The
ENGINEERS' DIGEST

A World Review of
DESIGN & PRODUCTION · RESEARCH & DEVELOPMENT

VOL. XXI No. 3 MARCH, 1960

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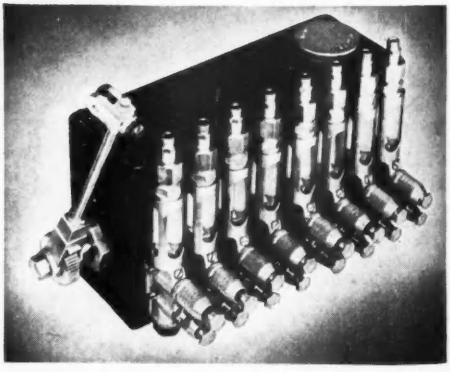

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Annual Subscription Rates:
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Printed in Gt. Britain by THE ALCUIN PRESS, Welwyn Garden City, Hertfordshire, and published monthly by the proprietors, ENGINEERS' DIGEST LTD., 120 Wigmore Street, London, W.1.

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The MINIDIGEST

According to a short report in *Materials in Design Engineering* for January 1960, a **new heat-treating process,** developed by the Research Development Corporation of America, has already been found to increase the yield strength of a considerable number of high-strength materials by as much as 35%, without, however, sacrificing ductility. It is also stated that the new process, details of which are not as yet available, pending patent clarification, results in a reduction of residual stresses, increased resistance to crack propagation, reduced notch sensitivity, reproducibility of structure and properties, and the elimination of size effect, grain growth in martensitic alloys, and composition sensitivity. Distortion after heat treatment is claimed to be held to between 0·0002 and 0·0003 in. per inch.

* * *

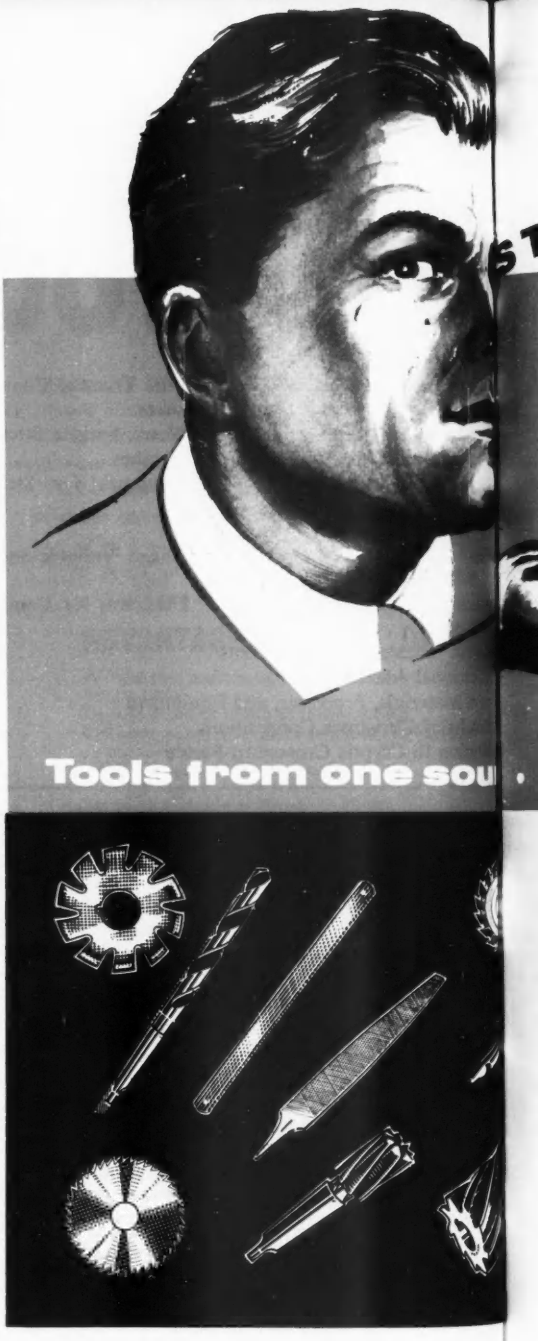
As indicated in a report in *Maschinen und Elektrotechnik* (No. 2, 1960), an Austrian firm has succeeded in producing **lead of exceptional purity** for shielding nuclear reactors. The material has a total impurity content of only 0·0005%, i.e., twenty times better than that required by specifications, and parts weighing up to 10 tons have already been cast and have been found to be free from voids and inclusions.

* * *

According to a brief report in *Electronics* (January 8, 1960), the U.S. Army Signal Corps Research and Development Division has constructed a **gallium phosphide diode** which is capable of withstanding temperatures that are seven times higher than those of silicon and germanium. Switching devices of this material, which resembles yellow ground-glass, have also been designed. Its ability to operate under conditions of extremely high temperature may well make it suitable for use in electronic components for missiles, satellites, and space probes.

* * *

As described in *Liteinoye Proizvodstvo* for February 1960, a study has recently been carried out in Russia to investigate the **causes of inverse-chilling in cast-iron piston rings.** In tests on a number of piston rings made of a cast iron containing from 3·7 to 3·9% C, 2·6 to 3·04% Si, 0·6 to 0·9% Mn, 0·45 to 0·6% P, and up to 0·2% Cr and 0·1% S, it was found that one of the major factors influencing inverse-chilling was the silicon content of the castings. Thus, with a



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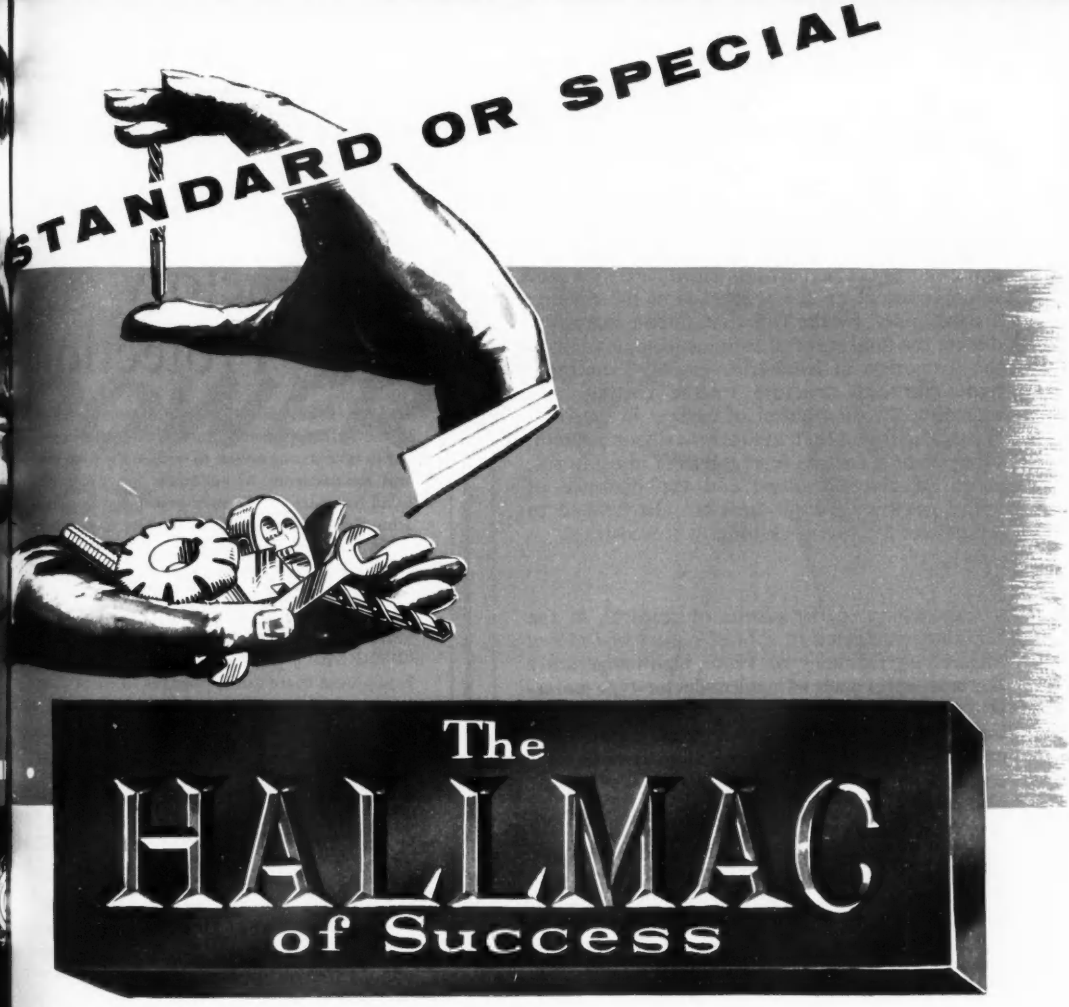

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silicon content between 2·88 and 3·04%, there was a substantial increase in inverse-chilling, whereas it was comparatively rare when the silicon content was reduced to between 2·60 and 2·66%. The harmful effects of increased silicon content on the properties of the castings are explained by the fact that silicon segregates during the final stage of solidification, leading to the formation of ledeburitic crystals, lending a hypereutectoid structure to the casting, and retarding the dissolution of carbon in the iron. It was also found that, apart from silicon content, other factors, such as segregation of phosphorus, speed of crystallization, and the presence of active centres of graphitization, also tended to contribute to inverse-chilling in the castings.

* * *

According to the results of research in the Ukraine, published in a brief report in *Product Engineering* (January 18, 1960), **high-temperature thermocouples made of semiconductor-type materials** are yielding promising results. Such combinations as molybdenum disilicide and boron carbide have already been tested, and thermal e.m.f.'s in the range of 40 μV/°F have been obtained, i.e., four times higher than those of platinum/platinum-rhodium thermocouples. In one design, the molybdenum disilicide forms the outer shell, the core being boron carbide, the two materials being welded at one end to form a rounded tip. At present under development for still higher temperature ranges is a titanium carbide/boron carbide thermocouple, which is expected to prove suitable for use up to 2300°F in non-oxidizing media.

* * *

A recent article in the Yugoslav journal *Elektrotehniski Vestnik* (No. 7–8, 1959), is concerned with the **heating-coil efficiency in high-frequency induction heaters.** It is pointed out that the part to be heated itself exercises an effect on the heating coil, so that its quality, i.e., the ratio of reactive and active impedance components, diminishes, and this relative decrease is used as the basis for measuring efficiency, as described in the article. The influences of the three main parameters on the efficiency of the heating coil are also presented, these parameters being the quality of the heating coil under no-load conditions, the coupling factor between the coil and the component to be heated, and the physical constant of the component. The article includes the results of measurements

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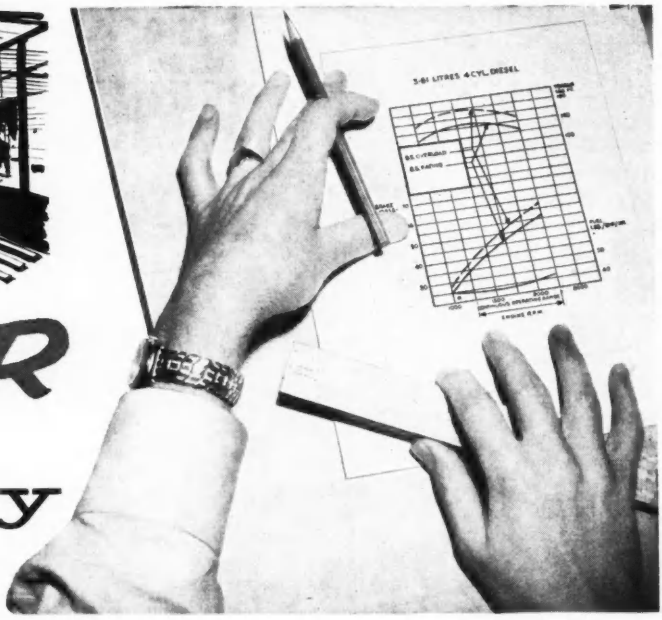

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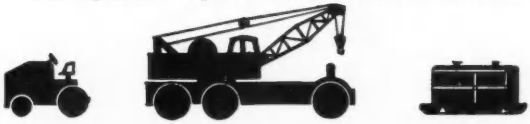

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The MINIDIGEST

made for typical examples of cylindrical parts of various materials in a single-layer heating coil and shows how difficulties originate in heating both good conductors and poor conductors.

* * *

A **new germanium transistor, operating in the low microwave frequency region,** and a very-wide-band amplifier employing this transistor, have been developed by the Bell Telephone Laboratories, of New York. To achieve high-frequency operation of this order, the dimensions of the transistor have been reduced to such an extent that the area of the active region is less than the cross-section of a human hair. Essentially, the device is a diffused-base, alloyed-emitter, *p-n-p* mesa transistor, designed for application as an oscillator at 3 kMc, or as an amplifier at 1 kMc and below, the mesa being only 0·0018 in. long and 0·0015 in. wide. The amplifier is said to have shown excellent stability, and the noise figure measured at 200 Mc is 5·5 dB with the feedback loops open.

* * *

With the current tendency towards sub-miniature components, particularly for use in such applications as transistorized circuits in missiles, computers, and electronic systems, it is interesting to note that what is believed to be the **smallest mass-produced incandescent lamp in the world** has been developed for such applications by the Sylvania Lighting Products Division of Sylvania Electric Products, Inc., of New York. The new lamp, designated the " Mite-T-Lite ", is stated to be tiny enough to pass through the eye of a darning-needle.

* * *

Developed by the Shell Chemical Corporation, of New York, and the Patterson-Sargent Co., of Cleveland, Ohio, a new amine-cured **epoxy-resin coating** is said to be **exceptionally resistant to the effects of nuclear radiation,** so much so that it will not fail even after prolonged exposure to high-intensity gamma radiation. The coating, which was specially developed to prevent the accidental leakage through concrete retaining walls of any water which might be contaminated by an accidental release of radio-activity, requires a curing agent to harden the resin. The same basic resin is used for the primer coat, for a second mastic coat (in which glass cloth is embedded), and for the finish coating.

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CONTRACTS

Humphreys & Glasgow Limited, in association with Petrocarbon Developments Limited, are to provide for the chemical industry of the German Democratic Republic an ethylene plant with a capacity of 40,000 tons per year. The order for the design and detailed engineering of the first phase of the project was signed in London last month by representatives of the East German Foreign Trade Enterprise DIA-Chemieausrüstungen and the British companies, and work will commence at once. The first phase is due for completion in December 1962. This is the first time that British companies have obtained a contract for a complete chemical plant for Eastern Germany, whose chemical industry ranks second, amongst the Eastern countries, only to that of the Soviet Union. The contract is part of the vast expansion programme of this industry and is one of the first results of the recently signed 1960 amendment to the 1959 trade agreement between the Federation of British Industries and the Chamber of Foreign Trade of the German Democratic Republic.

* * *

The Head Wrightson Machine Co. Ltd., a subsidiary of Head Wrightson & Co. Ltd., announce that the Steel Company of Wales Ltd. have placed an order with them for the supply of a high-speed cut-up line for their Abbey Works, valued at about £233,000. This line is one of the items in the new development programme designed to increase the output of steel sheets, and follows a previous order (for a similar cut-up line) recently completed for the same company. This line will take coils of cold-rolled strip weighing up to 56,000 lb and will convert them into sheets of different lengths, cutting to length being carried out at speeds of up to 700 fpm. After cutting up, the sheets will be automatically sorted and piled into packs of up to 40,000 lb in weight.

* * *

An order valued at more than £200,000 has been received by A.E.I. Heavy Plant Division from the Tinplate Division of the Steel Company of Wales for germanium rectifiers for a third tinning line at the company's Trostre Works, Llanelly. The equipment, which will consist of five large groups of rectifiers, will be used for the cleaning, pickling, tinning, and chemical treatment of strip in a range of widths from 27 to 38 in., and thicknesses from 0·006 to 0·015 in. The total capacity of the installation will be approximately 4000 kW, and the aggregate current more than 200 000 A at up to 24 V.

* * *

A contract worth more than £100,000 has been placed by British Railways Western Region with the Brush Electrical Engineering Co. Ltd., a member of the Hawker Siddeley Group, for the electrification of the Severn Tunnel pumping station at Sudbrook, near Chepstow, Monmouthshire. In the interests of engineering historical interest, the new modernization plan makes special provision for the preservation and display of the more outstanding items of the old plant. The equipment to be supplied includes a high-tension sub-station containing

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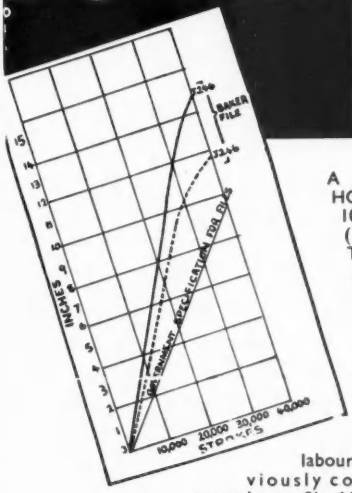

A typical LIGHTHOUSE Flat Bastard 10" file under test (The Sheffield Testing Works Ltd. Report No. 1827, 3rd July, 1959) filed 50% more material than a file of the standard required for Government departments. The saving in labour charges are obviously considerable. For example, to file 11" of test material, charging labour at 5/- per hour, **a LIGHTHOUSE file will save enough money to buy one dozen similar files** (when compared with a file which only complies with the standard specification).

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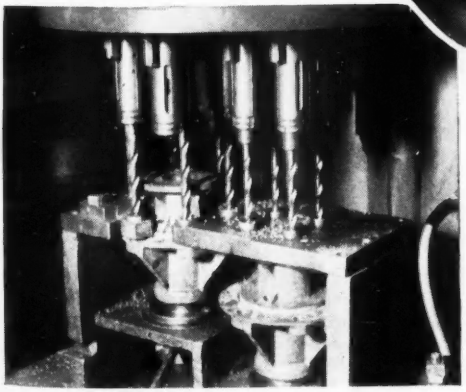

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* * *

Ashmore, Benson, Pease & Co. Ltd. (a member of the Power-Gas Group), Stockton-on-Tees, have recently received orders from Petroleos Mexicanos, through the Fluor Engineering & Construction Co., for fabricated refinery equipment of a value exceeding £250,000. The equipment, which is for the Minatitlan refinery, near Vera Cruz, Mexico, includes over seventy heat exchangers and two large vessels, each of 12 ft diameter and 214 ft length.

* * *

The Brightside Foundry and Engineering Co. Ltd., of Sheffield, has received an order from The Brymbo Steel Works Ltd. (a G.K.N. subsidiary) to manufacture and instal as main contractors a 32-in. blooming mill. The mill is required in connection with the second development scheme at Brymbo Steel Works, providing for a rolling capacity of up to 250,000 ingot tons a year and involving capital expenditure of over £2,000,000. This balances the steel-producing capacity installed under the first development scheme. The English Electric Co. Ltd. are to supply the electrical equipment for the mill.

* * *

A contract for the design and provision of the most advanced irradiated fuel element cave laboratory in the world with a capital value approaching £1,000,000 has been awarded to E. G. Irwin and Partners Ltd., consulting engineers, of London, by the U.K. Atomic Energy Authority. The laboratory is being installed in the blower houses of No. 2 reactor of the Windscale works, Cumberland, which closed down as a safety measure after the incident in 1957. The laboratory is designed to handle several thousand fuel elements a year from the nuclear power stations, as well as from experimental reactors.

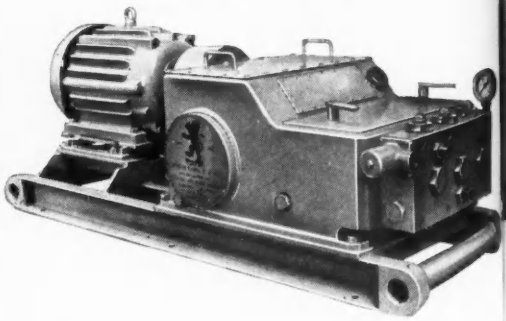
NEW

worm drive hydraulic pump

incorporating many interesting features

This pump is specifically designed as a mining hydraulic pump and incorporates many features based on our long experience of mining duties. In particular we would mention—

- *COMPACT DESIGN OF MINIMUM DIMENSIONS*
- *ALL STEEL CONSTRUCTION*
- *LOW PLUNGER SPEEDS*
- *MINIMUM WEIGHT FOR EASE OF HANDLING*
- *EASE OF OPERATION*
- *MINIMUM MAINTENANCE*
- *EASE OF DISMANTLING*



The unit is suitable for operation with water, water soluble oil mixture and hydraulic oil.

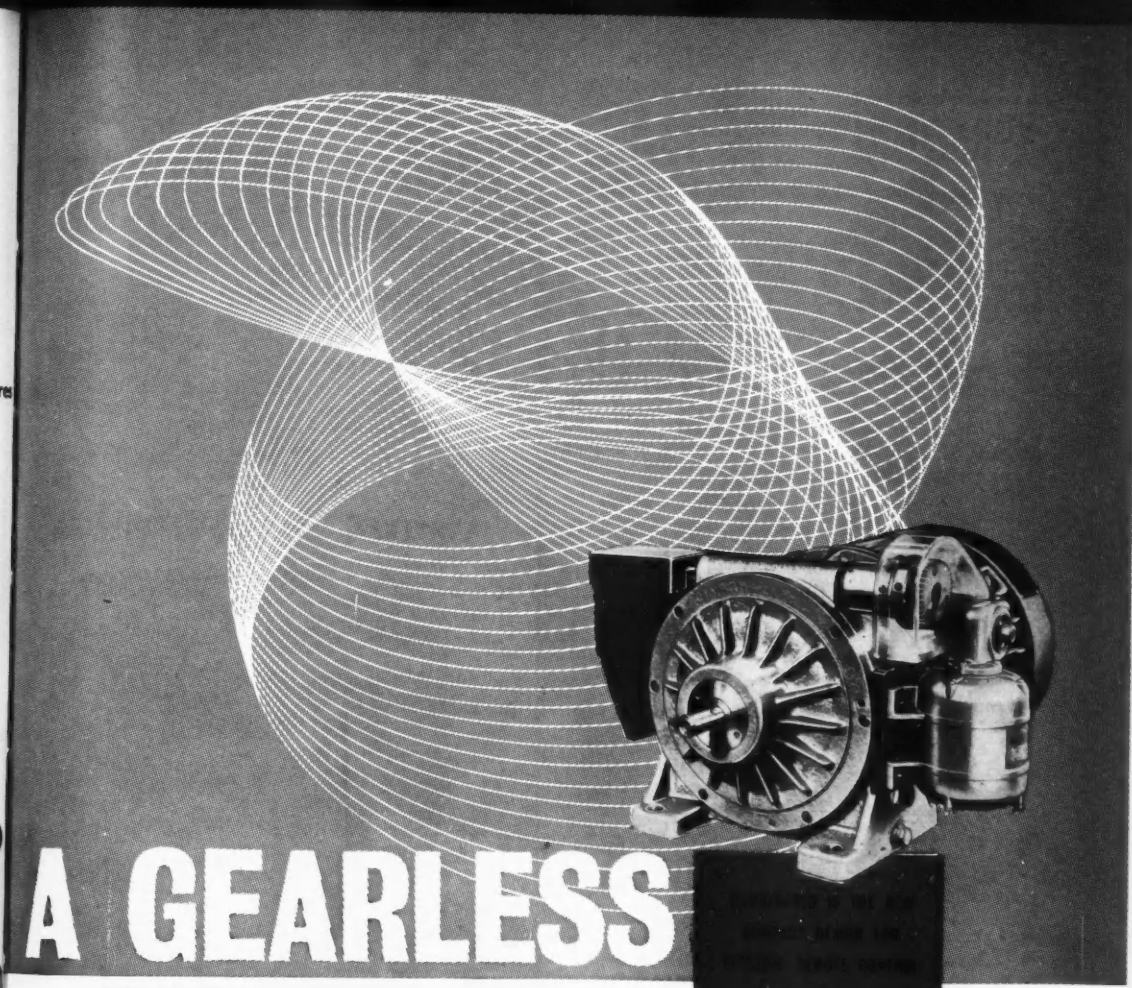
Write for literature.

Joseph Evans

JOSEPH EVANS & SONS (WOLVERHAMPTON) LTD.
Works: Culwell Works, Wolverhampton, England.
Tel: 27431 (5 lines)

London Offices: Pulsometer House, 20/26 Lamb's Conduit Street, London, W.C.1. Tel: HOLborn 1402

Branch Offices at Glasgow, Manchester, Birmingham, Cardiff, Newcastle, Derby.



A GEARLESS GEARBOX

- Range 1/33 h.p. to 15 h.p.
- 9 to 1 stepless speed variation
- Constant power transmission
- Flange mounted motors (when required)
- Flange mounted Reduction Gears for low output speeds
- Exceptionally light, sensitive and accurate control of speed settings by handwheel, pneumatic, mechanical or electrical remote control.
- Service reliability resulting from a simple design.
- Compact, vibrationless and silent.

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VARIABLE SPEED GEARS

MECHANICAL HANDLING EXHIBITION
EARLS COURT 3-13 MAY
SEE OUR EXHIBIT

PERSONAL

Mr. T. Haas, Dipl. Ing., A.M.I.Mech.E., A.F.R.Ae.S., has been appointed Head of the recently created Desing Advisory Service of the British Welding Research Association, of Abington Hall, Cambridge.

* * *

Following the decision to re-organize their executive management, **Mr. E. J. Boag,** previously works manager of the Phosphor Bronze Company Limited, has now been appointed director and general manager of C. & L. Hill Ltd. and its subsidiaries. **Mr. W. A. Bannister** becomes sales director, and **Mr. L. E. Morris** continues as works director.

* * *

It is announced by Rubery, Owen & Co. Ltd., of Darlaston, South Staffs., that a new department in the Motor Division of this company has been formed. This department will be called the Trailer Equipment Department and will be under the joint management of **Mr. J. T. Pierce** and **Mr. E. Pike.**

* * *

Following the recent death of **Mr. J. Kenyon, M.Sc.,** chief electrical engineer of Keith Blackman Limited, **Mr. H. W. Wright, A.M.I.E.E.,** has been appointed head of the electrical department at the head office and works at Tottenham, London, N.17.

* * *

Associated Electrical Industries Ltd. announce that **Mr. L. C. Richards,** until recently chief engineer of their Transformer Division in Manchester, has become chief engineer to Heavy Electricals Ltd., India, which is the Indian-Government company building the important heavy eleetrical-plant manufacturing centre in Bhopal.

* * *

Mr. J. Samuels, who, as a member of the board of Winston Electronics, Ltd., of Shepperton, Middlesex, has been purchasing director for several years, has now been appointed works director in charge of production.

* * *

Mr. F. N. Yates has been appointed commercial manager of Seton Creaghe Engineering Ltd., of Park Royal, London, N.W.10, and will be responsible for the marketing of special equipment developed by the company for use in a wide range of applications, including nuclear, electronic, and chemical plant.

* * *

It is announced that **Mr. P. Wrightson, O.B.E.,** managing director of Head Wrightson & Co. Ltd. since 1955, has been appointed vice-chairman and managing director.

* * *

The F'AG Bearing Company Limited, of Wolverhampton, the U.K. sales organization of Kugelfischer George Schafer & Co., of Schweinfurt, Germany, an-

It's worth looking into

HILGER PRODUCTION PROJECTORS

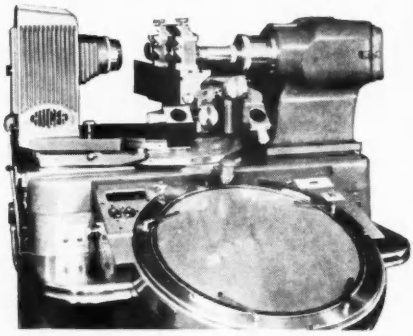
to see increased efficiency and a saving of time in the

GAUGE-CONTROL ROOM
DETAIL INSPECTION DEPARTMENT
TOOLROOM · MACHINE SHOP

Rapid routine inspection. Checking form tools and gauges, gear hobs, worm hobs, thread milling hobs, and hand filing against templets.

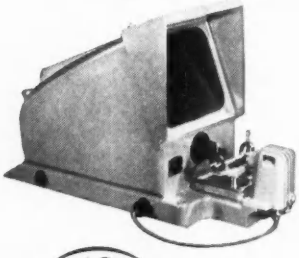
Write for details of our complete range of projectors.

The versatile
UNIVERSAL MEASURING PROJECTOR



This valuable multi-purpose projector will check gauges, tools and hobs throughout your inspection and gauge-control departments and will save time and manpower. It takes all kinds of objects up to 14 inches long and 8 inches in diameter, and weighing up to 60 pounds. It can be supplied with micrometer or glass scales. The projection screen has a usable diameter of 20 inches; a circular protractor enables readings to be taken to 1 minute of arc.

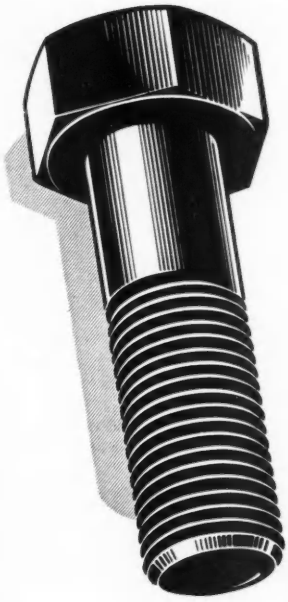
The inexpensive **CHEKKER PROJECTOR**



Room can easily be found for this little instrument. Built with Hilger precision for high accuracy and maximum utility in the workshop and the inspection department, it can be mounted vertically or horizontally.

HILGER & WATTS

HILGER & WATTS LTD
98 St Pancras Way London NW1



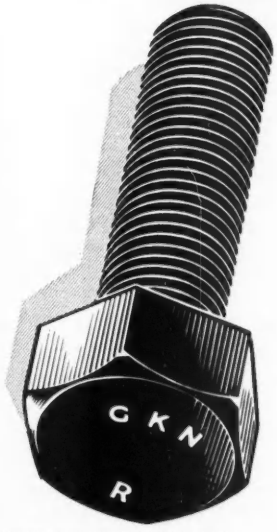
6 facts

1 GKN 'R' Bolts can be used anywhere on any engineering job because they are made to the close tolerances laid down in BS.1083 or BS.1768.

2 They are up to 50% cheaper than other Precision Bolts.

3 They are made on the most up-to-date plant in Europe, by methods which ensure perfect grain-flow in heads and threads, and no stress lines.

GKN R HIGH TENSILE BOLTS



4 From raw material to finished Bolt, they are subject to the strictest Quality Control.

5 Because of their 45 Tons Minimum Ultimate Tensile Strength, and 34 Tons Yield Stress, *smaller* 'R' Bolts can be used, and designers can therefore reduce the size and weight of their components.

6 The bolts are packed in strong cartons, are of good appearance and look well in your job.

GUEST KEEN & NETTLEFOLDS (MIDLANDS) LTD.,

BOLT & NUT DIVISION: ATLAS WORKS, DARLASTON, S. STAFFS

Telephone: James Bridge 3100 (10 lines) Telex: 33-228

D/R/123.

PERSONAL

nounce the appointment of **Mr. J. W. H. Nicholson** as advertising and publicity manager. The company has also opened a further branch at 69 Temple Street, Wolverhampton (Tel: Wolverhampton 20386) and another new branch office at 86 Bristol Street, Birmingham 5 (Tel: MIDland 9209). The Birmingham branch will be under the management of **E. B. Steer,** and the Wolverhampton branch under the management of **Mr. V. Sedgeley.**

* * *

Mr. J. Mackenzie-Mair has been appointed to the board of Steel, Peech and Tozer, a branch of the United Steel Companies Limited, and assumes the title of director and commercial manager. **Mr. W. T. Vizer Harmer** remains a full-time director of Steel, Peech and Tozer.

* * *

It is announced that **Mr. W. Padley, C.M.G., O.B.E.,** has been appointed to the board of Metal Industries Limited. Mr. Padley will relinquish his position as managing director of Brookhirst Igranic, the electrical subsidiary of Metal Industries Limited, and will be succeeded in this capacity by **Mr. A. B. Vickery, O.B.E.** Also, following the acquisition by Metal Industries Limited of Lancashire Dynamo Holdings Limited, **Sir Charles Westlake** (chairman) and **Mr. John Black** (deputy chairman) of Metal Industries have been appointed chairman and deputy chairman respectively of Lancashire Dynamo Holdings, from which company **Lt. Col. G. S. Marston** has resigned as chairman, managing director, and director. **The Earl of Halsbury** remains vice-chairman of Lancashire Dynamo Holdings.

* * *

Mr. E. G. Wakeling, general manager of Advance Components Limited, of Ilford, Essex, has been elected a director of the company.

* * *

The Plessey Company Limited, of Ilford, Essex, announce that **Brigadier J. D. Haigh, O.B.E., M.A., M.I.E.E.,** has been appointed divisional manager of their Capacitors and Resistors Division, Swindon.

* * *

It is announced by the Rockwell Machine Tool Co. Ltd., of London, N.W.2, that **Mr. H. P. Potts** has joined the board of the company.

MR. H. J. STONE

It is with deep regret that we announce the death on February 24th, 1960 of Mr. Herbert John Stone, M.C., M.I.E.E., a director and general manager of British Insulated Callender's Cables Limited. Mr. Stone was also chairman of British Insulated Callender's (Export) Ltd. and deputy chairman of British Insulated Callender's (Submarine Cables) Limited, of British Insulated Callender's Construction Company Ltd., and of British Copper Refiners Ltd.

NOW!

HYDRAULIC CIRCUITS

can be bought in a package!

THE ARMSTRONG HYDRAULIC ACTUATOR

enables you to install first-class hydraulic circuits in the easiest and most economical way in the world.
You can select a combination of the various types of Armstrong Actuator units to suit your individual requirements. Efficient assembly requires only elementary engineering knowledge: simple instructions are provided and stock embodiment items supplied.
An Armstrong Actuator does away with the need for heavy or complicated linkages and gives none of the troubles that tend to crop up with links, levers or cams. Once installed and charged it will function for as long as the machine or structure in which it is embodied—smoothly and efficiently. This bold new conception of hydraulic control has behind it the vast experience gained by the Armstrong Patents Company Limited of Beverley. They alone because of their unique position in the field of hydraulic engineering are able to offer Actuators of this quality at the price.
Armstrong "Off-the-Shelf" Actuators and pump units manually or power operated—put so many possibilities "within your reach" that early investigation is advised.
Ask for leaflet APL 51/18.

HYDRAULIC A-Z

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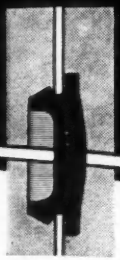
EASTGATE, BEVERLEY, YORKS
Tel. Beverley 82212

A new Grommet development

THE DOUBLE SEALING EMPIRE RUBBER GROMMET

infinitely accommodating in use: considerably reduces range of sizes because the same grommet can be used with several plate thicknesses or cable sizes



PAT. APP. No. 5255/59

This newly developed self-conforming grommet, because it is immediately self-locking against the elements, is the solution to many of an engineer's sealing problems.
Any one size will not only accommodate itself to a variety of mounting plate thicknesses, but (designed for cable or control rod) will take these in a variety of sizes and be weather-, water- and dust-proof at a variety of angles to the cable or rod.

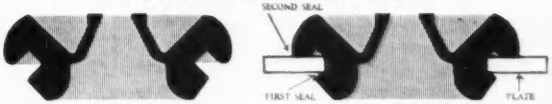
Because of its capacity to conform to many varying requirements, it enables a workshop stock range of grommets to be reduced to perhaps one tenth of that at present maintained.

THE NEW BLIND GROMMET

FREE

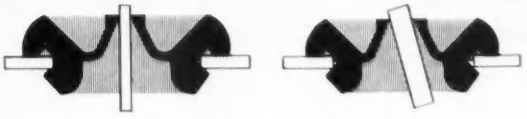
Note how when sprung into position the grommet provides a perfect double seal by its own permanent pressures. The angled groove also creates a tight pressure hold on the metal plate.

THE NEW DESIGNED GROMMET

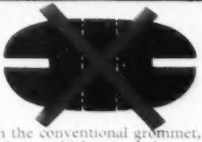


FREE FITTED

In the cable grommet variety the same double pressure seal is created, allied to tight seal on various diameters of cable. This new grommet gives sound sealing at *all* vital points.



A useful feature of this cable grommet is that by reason of the designed taper of the cable entry and the flexibility of the web, a considerable angle of cable entry and a variety of cable size are possible. This avoids necessity for special grommets with angled bores.



In the conventional grommet, only one thickness of plate and only one size of cable can be accommodated. No effective seal is afforded by the parallel groove.

Now being produced in a range of sizes.

THESE GROMMETS WILL SOLVE YOUR SEALING PROBLEMS.

ENQUIRE
for catalogue section and detailed particulars.

EMPIRE RUBBER COMPANY · DUNSTABLE · BEDFORDSHIRE · ENGLAND

BUSINESS NOTES

An agreement has recently been concluded between **D. Napier & Son Limited,** of London, W.3, a member of the **English Electric Group,** and the **Sierracin Corporation,** of Burbank, Cal., U.S.A., whereby Napier has been granted the exclusive rights to manufacture, use, and sell the " Sierracote " and " Sierraglo " processes in the U.K. and in Europe. " Sierracote " is a transparent, conductive coating used for heating aircraft windscreens and cockpit canopies when de-icing and demisting are required, and will therefore act as a complement to the Napier " Spraymat " de-icing system, already in use on many modern civil and military aircraft.

* * *

It is announced that an agreement has been signed between **Head Wrightson & Co., Ltd.,** of London, S.W.1, and the **Belco Division of the Bogue Electric Manufacturing Co.,** of Paterson, N.J., U.S.A., who are well-established in the field of water-treatment and trade waste-disposal plants. The agreement enables Head Wrightson to design, engineer, and build plants of this type throughout the world, with the exception of the North American continent, and the design and manufacture of this equipment will be handled by **Head Wrightson Processes Ltd.,** who have moved to 20–24 Old Street, London, E.C.1.

* * *

In order to achieve a much larger South African participation in the production of motor-vehicle components, an agreement has been signed by **Rubery, Owen & Co. Ltd.,** of Darlaston, and the **Vanderbijl Engineering Corporation Ltd. (Vecor),** of Vanderbijlpark, South Africa, who are the largest comprehensive engineering works in the Southern Hemisphere, for the manufacture in the Union of South Africa of wheels, axle housings, petrol tanks, chassis frames, body pressings, and other motor-vehicle components.

* * *

It is announced by **May & Baker Ltd.,** of Dagenham, Essex, that, from March 21, the address of **M & B Plastics Ltd.,** their subsidiary company, has been changed to 23–25 Eastcastle Street, London, W.1 (Tel: LANgham 0721). The telegraphic address remains the same.

* * *

Britain's first large-scale plant for machining beryllium, recently opened in Coventry, has been built for **Sir W. G. Armstrong Whitworth Aircraft Ltd.,** a member of the **Hawker Siddeley Group,** and will produce beryllium components for the latest type of nuclear reactors.

* * *

A new associated company, **Automac Ltd.,** has been formed to take over all the installation, repair, and engineering work previously carried out by **McKellen Automation Ltd.** Mr. G. M. P. McKellen, who remains a director of the latter company, has been appointed managing director of Automac Ltd., the address of which is Throstle Grove Works, Great Egerton Street, Stockport, Cheshire. (Tel: STOckport 6767.) McKellen Auto-

FUEL EFFICIENCY & POWER FOR INDUSTRY EXHIBITION

27th APRIL—6th MAY, 1960

Grand Hall OLYMPIA London

The 1960 Fuel Efficiency & Power for Industry Exhibition will be the largest display of fuel and power-saving equipment ever to be shown. Nearly 150 exhibitors will demonstrate the widest possible range of fuel efficiency and power-saving equipment, including the following:–

- Every conceivable type of Steam Raising Plant.
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- Liquid Fuel and Coal Firing Equipment
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- Oil Storage
- Gas and Electrical Furnaces
- Refractory and Insulating Materials
- Gas Producers
- High and Medium Pressure Hot Water Boilers
- Industrial Fuels
- Nuclear Power and many other types of equipment associated with Efficiency in the generation and utilization of Heat and Power.

This is, therefore, an opportunity for you to see all the latest developments and equipment associated with Fuel Efficiency & Power for Industry.

An important series of Technical Conferences will take place during the Exhibition in the Conference Hall. A programme of Technical Sessions will be available at a later date.

For full details please write to the Organisers:

PROVINCIAL EXHIBITIONS LTD.

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(In association with F. W. BRIDGES & SONS LTD.)

FOR METAL-ARC WELDING OF HIGH-NICKEL ALLOYS USE THE RIGHT ELECTRODE

For welding the high-nickel alloys special electrodes have been developed to give the best results. *Don't spoil good materials by using the wrong electrode.*

MATERIAL	METAL-ARC ELECTRODE
'A' Nickel Low Carbon A Nickel Duranickel Age Hardenable Nickel alloy	'131' Nickel
MONEL* *corrosion-resisting alloy*	'130' MONEL
'K' MONEL* *age-hardenable corrosion resisting alloy*	'134' K MONEL
NI-O-NEL* *corrosion-resisting alloy*	'135' NI-O-NEL
CORRONEL* 210 | *corrosion-resisting alloy*	CORRONEX* B
CORRONEL* 220	
INCONEL* *oxidation-resisting alloy*	'132' INCONEL
INCOLOY* *heat-resisting alloy*	INCO-WELD 'A'

MATERIAL	METAL-ARC ELECTRODE
INCOLOY DS *heat-resisting alloy*	INCO WELD A
NIMONIC 75 *heat*	NICREX 4 or CHROMAC N
NIMONIC 80A *resisting*	
NIMONIC 90 *alloys*	
BRIGHTRAY*B	NICREX* 3
BRIGHTRAY*C	NICREX* 4 or CHROMAC* N
BRIGHTRAY*F *high-temperature electrical resistance alloys*	INCO-WELD* A
BRIGHTRAY*H	NICREX* 4 or CHROMAC* N
BRIGHTRAY*S	NICREX* 4 or CHROMAC* N

* *Trade mark*

SEND FOR THIS BOOKLET

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FD/M29/3

We have available a 16-mm sound film in colour entitled '*Welding of Wiggin High-Nickel Alloys*' which is available without charge for showing to engineering societies, training classes, etc.

HENRY WIGGIN & COMPANY LIMITED · WIGGIN STREET · BIRMINGHAM 16

TGA M29

★ **SEE OUR EXHIBITION—WIGGIN NICKEL ALLOYS in industry—HELD AT 45 PARK LANE, LONDON, W.I. 21st–25th MARCH**

BUSINESS NOTES

mation Ltd., who are agents and stockists for a number of leading electronic-instrument manufacturers, will continue to operate their sales organization from 122 Seymour Grove, Old Trafford, Manchester 16.

* * *

Representing the first step in their expansion programme, **Solus-Schall Limited,** specialists in non-destructive testing, have moved their sales, administration, and accounts departments to new premises (County Building, Honeypot Lane, Stanmore, Middlesex. (Tel: WORdsworth 4300.)). The service department will, for the time being, continue to operate from 15/18 Clipstone Street, London, W.1 (Tel: MUSeum 5080), but it is planned that the entire organization, including the manufacturing sections, will be under the same roof within the next month or two.

* * *

Arrangements have recently been concluded between the **Aget Manufacturing Company,** of Adrain, Michigan, U.S.A., and **Gaston E. Marbaix, Ltd.,** of London, S.W.11, for the latter company to represent in Great Britain and Western Europe the American company, who produce a range of oil and cutting-fluid mist-, fume- or vapour-collecting and condensing drums for use with machine tools and other equipment.

* * *

It is announced that the **Startrite Engineering Co. Ltd., Startrite Machine Tool Co. Ltd.,** and **Startrite Sales Ltd.** have changed their address to Darland Hall, Star Mill Lane, Chatham, Kent (Tel: Gillingham 50151/2/3).

* * *

With a view to greatly increasing the sale of British-designed electronic equipment in America, an agreement has recently been concluded between **E. M. I. Electronics Ltd.,** of Hayes, Middlesex, and the **Fairbanks Whitney Corporation,** of New York, who will undertake to market in the U.S.A. most of the range of electronic equipment designed and manufactured by E. M. I.

* * *

Planned to centralize the assembly of their colloid mills and mixers for industrial applications of all kinds, extensions to the main offices and laboratories have recently been completed by **Premier Colloid Mills Ltd.,** of Hersham Trading Estate, Walton-on-Thames, Surrey.

* * *

It is announced by **EFCO Ltd.** and **Stein & Atkinson Ltd.** that they have joined forces in a new company, the **Foundry & Metallurgical Equipment Co., Ltd.,** with headquarters at Netherby, 161 Queens Road, Weybridge, Surrey. This company will design, manufacture, and supply an extensive range of foundry equipment, including gas- and oil-fired crucible melting furnaces; gas-, electric,- and oil-fired annealing furnaces and ovens specifically for foundry use; batch and continuous core stoves; core blowers, mould driers, and sand driers; shell-moulding and mould-closing machines; and gravity

INDUSTRIAL LUBRICANTS

GREASES, GREASE COMPOUNDS

and Molybdenum-Disulphide (MoS_2) Specialities

Make this simple test—

and this

Prove for yourself by placing a small amount in an ordinary refrigerator—or hold over a flame.

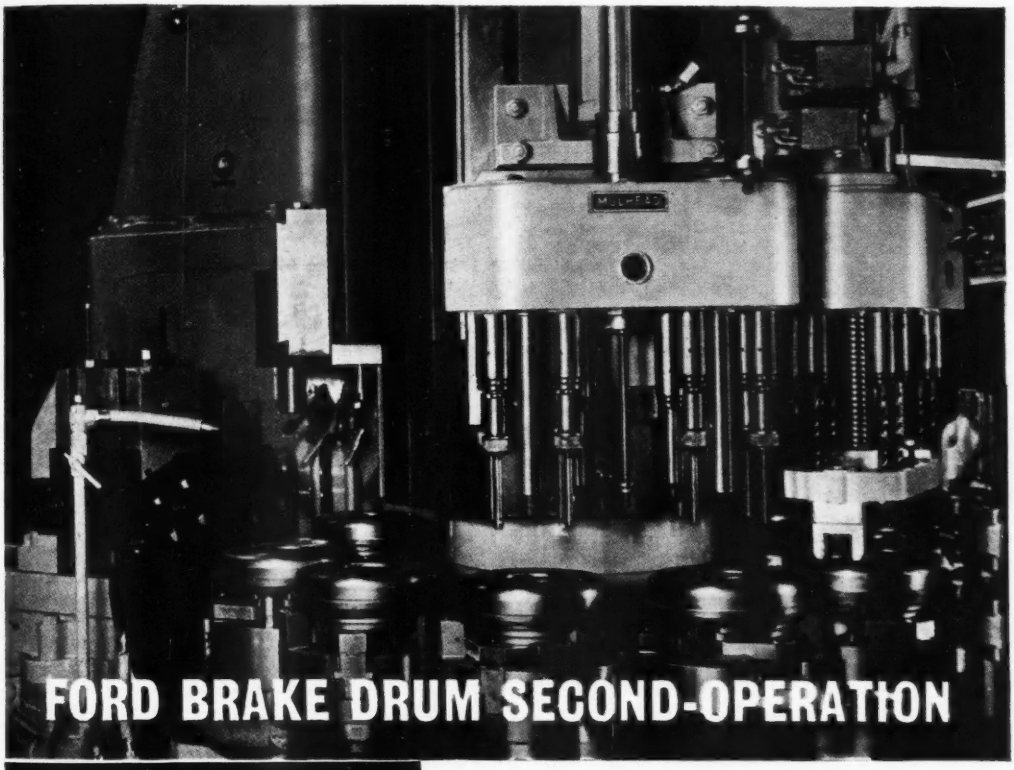
Ask for a free sample and mention your lubrication problem.

JET-LUBE LTD.

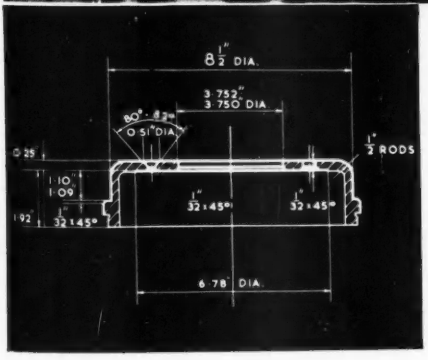
PARK LANE, FALLINGS PARK, WOLVERHAMPTON

TELEPHONE: WOLVERHAMPTON 31295

London Office: 22, Headfort Place, S.W.1. *Telephone: BELgravia 6146*



FORD BRAKE DRUM SECOND-OPERATION



MACHINED IN 40 SECONDS

The use of special Mulhead multi-drill heads on the Ryder Verticalauto enables drilling, reaming, countersinking and back-chamfering operations to be performed in addition to standard boring and facing work.

The second operation on this Ford Brake Drum is completed at very high output rates on this 12-spindle No. 10 Ryder Verticalauto

Ryder ***VERTICALAUTO***

Thos. Ryder & Son, Limited, Turner Bridge Works, Bolton, England.
Makers also of single spindle Rydermatics and Piston Ring Lathes.

BUSINESS NOTES

die-casting equipment. In addition, they will manufacture and supply, under licence, the EFCO-Diamond rotary reactor for desulphurizing iron and steel by a new method developed in the U.S.A. by the **Diamond Alkali Company.** The company will also offer complete hot-blast cupola plants embodying air heaters of the Escher type and with the latest water-jacketed reaction zone. The directors of the new company are Mr. D. F. Campbell (chairman), Mr. C. J. S. Atkinson, Mr. J. A. Monks, and Mr. C. H. Williams. The consulting metallurgist is Dr. A. G. Robiette.

* * *

With a view to expanding their distribution and servicing facilities in connection with their portable electric tools, **S. N. Bridges & Co. Ltd.,** of London, S.W.11, have opened new premises at 128/129 High Street, Bordesley, Birmingham 12, to serve the Midlands region.

* * *

It is announced that **Burton, Griffiths & Co. Ltd.,** of Kitts Green, Birmingham 33, who have held the representation for the **Gisholt Machine Company,** of Madison, U.S.A., for 67 years, covering this company's range of lathes and " Dynetric " balancing machines, are now the sole concessionaires in the U.K. for Gisholt superfinishing machines and " Fastermatic " automatic turret lathes. Burton, Griffiths & Co. Ltd. have also been appointed sole agents in the U.K. for the **Gisholt Machine Company (G.B.) Ltd.,** for the range of machines to be manufactured for them by the **Lang-Gisholt Machine Company Ltd.,** at Johnston, Scotland.

* * *

With the object of expanding the instrumentation and control interests of both companies, a new company, **Drayton-Southern Limited,** with an authorized capital of £100,000, is being jointly formed by **Southern Instruments Limited,** of Camberley, and **The Drayton Regulator and Instrument Company Limited.** The chairman of Drayton-Southern Limited will be Col. P. H. Lloyd, T.D., D.L., and the managing director Mr. J. G. Lubbock. The remaining members of the board will be drawn from the respective boards of the two parent companies.

* * *

Intended to supplement their normal activities by undertaking contracts for large fertilizer and chemical projects abroad, a new joint company, **Chemical Works Projects Limited,** with registered offices at Simon House, 28/29 Dover Street, London, W.1, has been formed by **P. G. Engineering Limited** (a member of the **Power-Gas Group**), **Humphreys & Glasgow Ltd.,** and **Simon-Carves Limited.** The board will consist of Mr. J. P. V. Woolam, Mr. G. Gresle Farthing, and Mr. R. W. Rutherford, who will be the first chairman.

* * *

It is announced by **Modern Electrolytic Patents and Processes Ltd.,** of Mark Road, Hemel Hempstead, Herts., who are pioneers in the U.K. of electropolishing, that their associates in Germany, **Elektrolyse G.m.b.H.,** of Munich, the largest supplier of electropolishing plant and chemicals in Europe, have concluded license agreements with two leading plating supply houses, i.e., **Friedrich Blasberg,** and **Dienert & Co.** Under this agreement, the three German companies will supply " Poligrat " electrolytes to German industry and, in addition, will pool their experience and information and provide a central technical service. The electropolishing processes covered by this new agreement have been developed by the **Battelle Institute** in the U.S.A., by the **Jacquet Hispano-Suiza Group** in France, and by Elektrolyse G.m.b.H in Germany, and are identical with those offered in the U.K. by Modern Electrolytic Patents and Processes Ltd.

* * *

Although **Dunlop Japan** has recently completed fifty years of manufacture of rubber products in Japan, it has long been recognized that Japanese participation in the ownership of this company is becoming more and more desirable. As a result, it is announced that **Sumitomo Electric Industries,** of Osaka, are to become shareholders in Dunlop Japan, with a holding of nearly 29%. Under the terms of the agreement, recently signed in Kobe, Dunlop Japan is to increase its issued share capital from 500,000,000 yen (£500,000) to 1,750,000,000 yen by the capitalization of reserves and the subscription in cash of 750,000,000 yen by **Dunlop England** and Sumitomo. A major expansion programme is now planned and includes the modernization and enlargement of existing manufacturing facilities in Kobe and the erection of a second tyre factory, probably in the Nagoya area, scheduled for completion in the middle of 1961.

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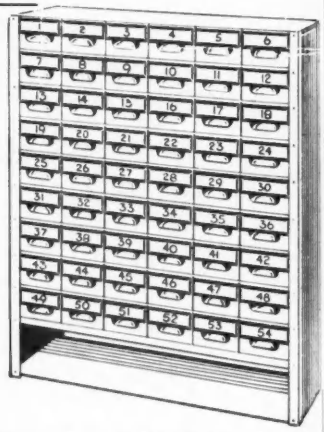
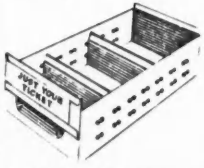
12" DEEP





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LENGTH	WIDTH	THICKNESS	PITCHES OF TEETH
10"	½"	.025"	18, 24, 32
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S133

NEWS ROUND-UP

Vinyl Coatings for Protecting Large Storage Tanks

Built on a bluff overlooking the Pacific Ocean, three large fuel-oil tanks, each with a capacity of about 8,000,000 US gallons, are exposed to rain, hot coastal sun, smog, and salt-laden mist. As a result, these steel tanks, which have been erected to supply fuel oil to a new electric power station in Los Angeles, are exposed to markedly corrosive conditions, so much so that, even before they were completely assembled, their plates commenced to rust. It is now, however, reported by the Union Carbide Plastics Company, of New York, that both the immediate corrosion problems involved and those of long-term maintenance have been solved by applying a sprayed-on protective coating system, based on Bakelite vinyl resins. The system consists of three different vinyl-resin coating formulae, applied in a four-coat process, the total thickness of the combined system being a minimum of 0·008 in.

The first coat, a pigmented primer, was applied a few minutes after sandblasting the plates to remove accumulated rust and served to prevent the formation of new rust deposits before the application of the other coatings. The priming coat was followed by two coats of a special vinyl resin, while the final coat, consisting of a third vinyl formula which acts as a seal coat, gave the fuel tanks a glossy finish, from which rain can readily wash away dirt and dust.

New Headquarters for the Wakefield Castrol Group

Castrol House, the new headquarters for the Wakefield Castrol Group, is an impressive and fitting symbol of the success achieved by this all-British organization—the largest independent lubricating-oil group in the world.

Fifteen storeys in height and covering a site of nearly an acre, this glittering and attractive building of glass and concrete on the Marylebone Road, near Baker Street, London, features a twelve-storey glass tower which can be flood-lit internally through opaque green glass panels surrounding the building beneath windows on each floor. In addition to the normal office accommodation for a staff of about 800, Castrol House, with its gross floor space of 165,300 sq ft, contains two restaurants, a showroom, several conference rooms, a cinema, an underground garage for more than seventy cars, and, on the fourteenth floor, a residential suite incorporating five bedrooms mainly for the use of visiting Group executives from overseas. From this suite, there is access, via a spiral staircase, to an observation dome on the roof.

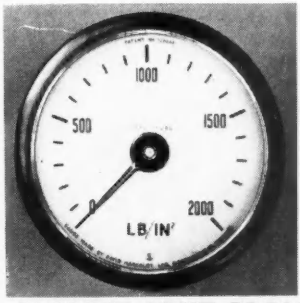
Enquiry into the Working of the Clean Air Act

A nation-wide inquiry into the working of the Clean Air Act of 1956 is being conducted by the National Society for Clean Air. A questionnaire is being sent to the 1700 local authorities in England, Wales, and Scotland who are responsible for administering the Act to ascertain how well, or otherwise, the Act is succeeding. In this connection, the Act, which followed the proposals of the Beaver Committee on Air Pollution, introduced so many new methods and principles for the prevention of smoke that it has become desirable to learn how effective it is proving to be in practice, what weaknesses or difficulties may have emerged, and whether any changes should be sought, either in the Act itself or in any of the regulations that have been made under it.

The questionnaire is in twelve main sections, each of which includes queries on points of detail, ranging from the number of cases of dark smoke emission brought to court, to the state of public opinion in proposed smoke-control areas. One of the needs, stressed by the Beaver Committee and allowed for in the Act, is in the field of education and publicity, and the questionnaire asks what is being done to make sure that the need for clean air is understood. The replies to the questionnaire, after being analysed, will be the subject of reports which are to be presented for discussion at the annual conference of the Society at Harrogate in October. It is anticipated that the information obtained and the inferences that may be drawn from it will be of considerable importance to all local authorities and to the central government itself.

Distillation Unit for Sea-Water

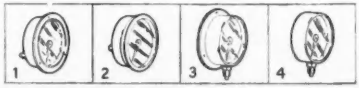
The world's biggest single-unit distillation plant, capable of producing 1,200,000 gallons of fresh water daily from sea water, sufficient for a town of 25,000 inhabitants, is being built by Buckley and Taylor Ltd., of Castle Iron Works, Oldham. The plant, which is of a new type, manufactured under the name of "Aquaflash", virtually constitutes a break-through in distillation techniques, and its output will be approximately 10%



THE DAVID HARCOURT
EVEREST UNIT PRESSURE GAUGE

This patented unit is recommended for the more important installations. It is available with four mountings as illustrated below with 4" and 6" diameter dials.

Narrow flange, with rear clamp fixing, this model has a black, shock-resisting plastic case and is made with 4" and 6" dials, (large illustration) and (2).
Flush fitting, with back connection (1).
Surface connection, with bottom connection (3).
Direct mounting, with bottom connection (4).



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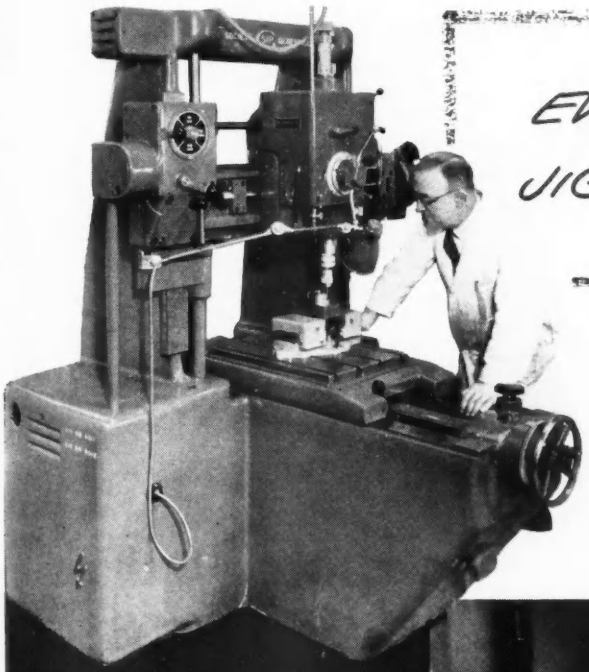
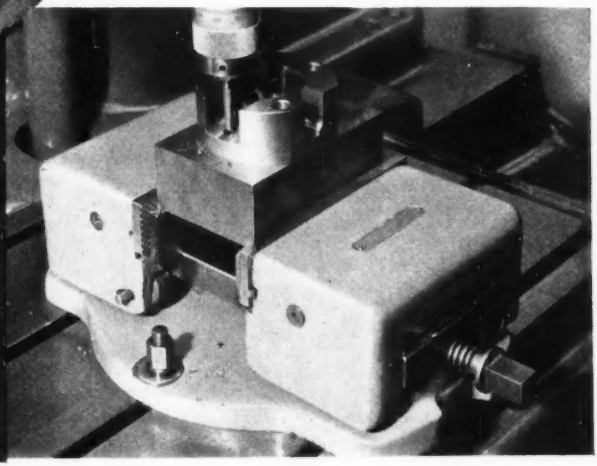


EVEN ON A JIG BORER...

Here is a Machine Vice with built-in precision. As its name implies, it actually grips the work hard down onto its table or parallels. An accurate set-up in seconds!

The illustrations show the boring of a location pin hole in a fuel pump assembly fixture at the premises of Messrs. AC-Delco, Liverpool, by whose courtesy the photographs are reproduced.

DOWN GRIP



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of the world's present land-based sea-water distillation capacity. The plant will occupy a space of roughly 165 ft long by 20 ft wide by 16 ft high, and its eight condensers, each weighing about 14 tons, will contain 83 miles of condenser tubes. Sea-water will be fed into the plant at the rate of over 5,000,000 pounds per hour, and the pumps needed to circulate the water will require a power input of more than 500 hp.

The basic principle of the process is that heated sea-water is sprayed into a vessel which is maintained at a low pressure, the water boiling instantly and the steam "flashing" off. In practice, the plant will consist of a number of flash vessels in series, maintained at progressively lower pressures corresponding to the successive falls in temperature of the brine. One of the main features of the plant is that the formation of scale will be minimized, and no chemical treatment of the sea-water feed will be necessary.

Exhibition of Nickel Alloys in Industry

Following the outstanding success of their previous exhibition in London, Henry Wiggin and Company Limited will stage a similar exhibition of Wiggin nickel alloys in industry at Park Lane House, 45 Park Lane, London, W.1, from March 21 to 25, 1960.

The object of this exhibition, which will be open daily from 10.00 a.m. to 8.00 p.m., closing at 5.00 p.m. on March 25, is to help engineers and designers to make the best use of the specialized alloys manufactured by the company. These alloys fall mainly into four groups, i.e., corrosion-resisting alloys, heat-resisting alloys, electrical resistance alloys, and materials with special properties. The display will include a large selection of actual components, sub-assemblies, and finished parts in which Wiggin materials play vital roles. During the exhibition, a series of lectures will be given on various subjects, including the "fabrication of high-nickel alloys", and a series on the uses of high-nickel and nickel-base alloys in the production of nuclear power, in heat-resisting applications, in the electrical and electronic industries, and in chemical engineering. Throughout the exhibition, the Company's technical staff will be pleased to answer visitors' queries, and publications covering the complete range of Wiggin products will be available. The exhibition will be augmented by a continuous showing of films on applications and fabrication of Wiggin products.

Spring Meeting of The Institute of Welding

The Spring Meeting of the Institute of Welding will be held at Droitwich from May 9 to 11, 1960, and will be devoted to novel welding processes and metal spraying. The provisional programme includes an opening reception at the Worcestershire Brine Baths Hotel, two morning sessions, for the discussion of technical papers, a choice of works visits, and a concluding dinner. The Conference centre will be at the Winter Gardens, Droitwich, and most of the supply manufacturers will be taking part in a small exhibition of photographs, literature, etc. Five papers on different aspects of metal spraying have already been prepared, and it is intended to devote the whole of one technical session to these papers.

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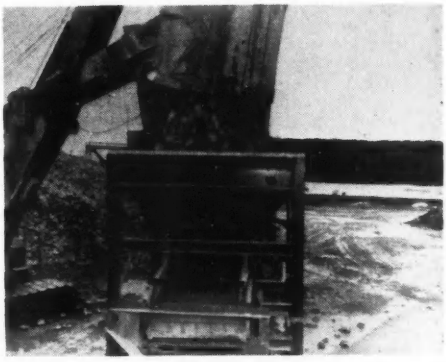
- ***(C) low cost maintenance***
- ***(D) reliable continuous operation under the most exacting site conditions***

These feeders are also available with non-plugging grizzly sections and Manganese steel liner plates. All units can be fitted with a variable feed device if required.

4' - 10' Grizzly Feeder operating in conjunction with portable stacker. Minus 12" limestone is dropped 10' to 15' from a 3 cubic yard bucket straight on to the Manganese Steel Feeder deck. The unit has been operating for six years, 10 hours per day at 350 tons per hour.



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NEW TECHNICAL BOOKS

The Ironfoundry Book. First Edition, 1959. 434 pages. Publishers: The Standard Catalogue Co. Ltd., 26 Bloomsbury Way, Holborn, London, W.C.1. Price: 42/- (35/- each for two or more copies).

Fulfilling the need for a complete guide to the capabilities and capacities of firms employed in the industry, this new reference book for the ironfoundry trade should certainly prove of great interest and value to all designers and users of iron castings. Compiled with the co-operation and assistance of the Council of Ironfoundry Associations, this comprehensive volume constitutes a reliable guide to the facilities, capacities, etc., of individual foundries, enabling users to contact suitable foundries for specific types of work, and also serves as a buyers' guide for all types of foundry equipment and materials.

Who's Who in the Motor Industry. Fourth Edition, 1959. 610 pages. Publishers: Temple Press Limited, Bowling Green Lane, London, E.C.1. Price: 42/-.

Constituting a complete and authoritative guide to the structure and composition of the British car and commercial-vehicle industries, this fourth edition of *Who's Who in the Motor Industry* contains a number of new features and has been thoroughly revised in all sections. Thus, innovations include lists of the overseas subsidiaries and associated companies of British manufacturers, the names and addresses of racing managers of companies interested in competitive motoring and details of the various competitions, and a comprehensive list of one-make car clubs.

The book includes all relevant details of all British manufacturers of cars, commercial vehicles, caravans and trailers, and suppliers of accessories, components, materials, and services, together with details of some 1900 distributors and main dealers and a biographical section providing personal information on about 1400 distinguished individuals in the motor industry or in other spheres associated with British motoring.

The Wire Industry Encyclopaedic Handbook, 1960. 10th edition. 542 pages. Publishers: *The Wire Industry*, 33 Furnival Street, London, E.C.4. Price: 25/-.

This considerably enlarged 1960 edition is, as usual, a comprehensive encyclopaedia of trade terms, types of wire processes and machinery used, etc., and a buyers' guide to wire, plant for processing wire, and machinery for making wire goods. Some 25 pages of tables of wire sizes and weights are included, and branded names of common use in the wire industry are identified. Other features include a guide to British Standards affecting all branches of the wire industry, details of associations, books of reference, and a bibliography.

Encyclopedic Dictionary of Electronics and Nuclear Engineering. By Robert I. Sarbacher, Sc.D. 1428 pages. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 160/-.

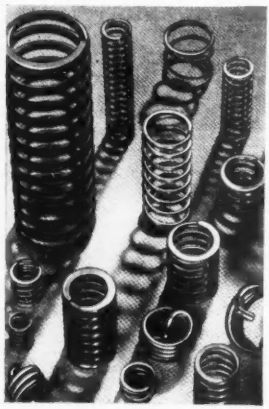
The outcome of twelve years of extensive and careful research, this quite outstanding book is without doubt the most up-to-date reference work of its kind. Containing more than 17,000 cross-references and more than 1400 illustrations, it is the first volume to include all terms, equipment, components, and systems in the fields of electronics and nuclear engineering; indeed, as an example of the extraordinary care taken to make it as comprehensive as possible, it may be mentioned that the word *antenna* has no less than 206 separate entries and 92 illustrations.

Although primarily concerned with electronics and nuclear engineering, it should be noted that the book provides valuable information and additional definitions in related fields. Thus, acoustical, chemical, electrical, physical, and mathematical-physical terms, devices, and systems are given where particular application is made to electronics and nuclear engineering. Equations, tables, design equations, statistical data, etc. are also included, where pertinent. In short, this book is of undoubted value as a reference work to all those engineers, scientists, technical writers, and others whose work and interests have any bearing on these fields. Furthermore, the information it contains is lucidly presented and authoritative, as is only to be expected of its author, who, among other positions, has served as Director of Research for the National Scientific Laboratories, Washington, D.C. and with leading American companies, and who now lectures at George Washington University and has his own consulting firm in Washington.

A Simple Approach to Electronic Computers. By E. H. W. Hershee, M.A.(Oxon.), D.C.Ae. 112 pp., 27 illustrations. Publishers: Blackie & Son Limited, 17 Stanhope Street, Glasgow, C.4. Price: 12/6.

In this compact, but most instructive, book, the author successfully presents in some detail and as simply as possible a few of the basic working principles of both digital and analogue computers, and provides a useful introduction to more advanced textbooks on the subject.

One fundamental result of this approach to the subject is that, by enabling a clear understanding of the elementary principles involved to be obtained, readers will begin to appreciate the essential simplicity of computers. As such, the book will have the salutary effect of dispelling the impression that electronic computers are endowed with superhuman powers—a popular belief fostered by misleading articles and reports in the press and the widespread and erroneous use of the term "electronic brain".



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3. Air-Power Equipment. A range of air-power equipment detailed in an 8-page brochure includes impact cylinders, valve-cylinder units, and solenoid-controlled air valves, as well as rotary feed tables and self-contained hydraulic units for the accurate control of machine or air-cylinder movement. A description is also given of a special hydraulic drilling and tapping unit, in which any number of drill units can be synchronized and interlocked for sequence operations.

4. Aluminised Asbestos. Providing all the advantages of fire-proof cover cloths, while comparing favourably in appearance with plastic and decorative cleading finishes, a new asbestos material, designated aluminised asbestos, is dealt with in a 6-page leaflet. This material, which achieves thermal economy by heat reflection, is claimed to be strong, durable, and impermeable to moisture. In addition, it can be easily fitted, applied over primary pipe insulation, or fabricated into mattresses.

5. Acrylic Stoving Finish. Details are given in a 6-page leaflet of a new acrylic stoving finish claimed to be of superior hardness when applied to ferrous and non-ferrous metals. Application is by spray gun and requires no special technique. The usual stoving temperature is 300° F at 30 min, but stoving time may be reduced in relation to temperature increase. Exceptional properties of the stoving finish include outstanding durability, complete colour retention, heat resistance up to 350° F, resistance to alkalis, solvents, and domestic oils and fats, as well as excellent print, mar, and scratch resistance.

6. Automation Equipment. Selected examples of automation equipment are presented in an illustrated 16-page brochure. The applications described include installations for tubeless-tyre fitting and inflation, power-assisted assembly of gear cages, automatic feeding and staking of tube-end fittings, automatic pick-up unloaders for rotary-table grinders, and loading of lathe chucks.

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8. Steel Shelving and Works Equipment. Issued as a guide to the range and manifold uses of shelving and works equipment produced by a leading manufacturer, an illustrated 40-page catalogue presents details, as well as a large number of typical applications, of the equipment. The range of industrial shelving covered includes open, closed, and ledge-type shelving, sliding-door cupboards, and multi-tier shelving, as well as warehouse, light, and library-type shelving.

9. Dynamometers. Designed for the accurate measurement of drill torque and lathe cutting forces and specially recommended for all research and technical establishments, the dynamometers described in detail in a 28-page brochure are built for accuracy to within $\pm 1\%$ and measure torque and axial effort in drills up to 35 mm in diameter. Distortion is eliminated by the use of two specially heat-treated transducers, and actual measurement is registered by an air-controller on a suitably graduated scale.

10. Resonance Screens. Eminently suitable for screening coal, coke, ore, limestone, potash, and a number of other materials, and for classification of various chemical products, a range of resonance screens is presented in an illustrated 8-page brochure. These screens, which have a low power consumption and permit easy amplitude adjustment to suit the properties of the materials screened, are specially recommended for applications where limited headroom demands horizontal layouts and where the transmission of vibrations to the supporting structures has to be avoided.

11. Automatic Injection-Moulding Machine. Designed to injection-mould, with or without an operator, up to 4 full ounces of polystyrene (6 full ounces using double feed) or 14·5 cu in. of any other granular thermoplastic material, an automatic injection-moulding machine is described in an illustrated 4-page leaflet. The main features of the machine are its simplicity in operation, versatility in moulding thermoplastic materials, and speed for filling and for cycling. The adjustable mould opening reduces lost motion, giving improved speed when moulding shallow parts.

12. Worm-Reduction Gear Units. The range of worm-reduction gear units described in an illustrated 40-page catalogue includes composite, geared-motor, and inverted-type single-reduction units for gear ratios of from 5 : 1 to 60 : 1 and right-angled, two-speed, horizontal, and fractional-type double-reduction units for gear ratios up to 3000 : 1. Principal dimensions, horsepower ratings, as well as recommendations for installation and operation of these units are included.

13. Torque Converter. A well-illustrated 12-page booklet intended as a simple introduction to the torque converter, without attempting to enter into its technicalities, presents a brief explanation of the various components and operating principles of torque converters. Information is included on possible applications of the torque converter, which can be used to best advantage where the load is of an extremely varying nature, such as in excavators, cranes, tractors, etc. Torque converters are also particularly adaptable for applications involving shock loads or short periods of overload on the power source, or where loads are rather constant, but extreme starting or accelerating conditions are encountered.

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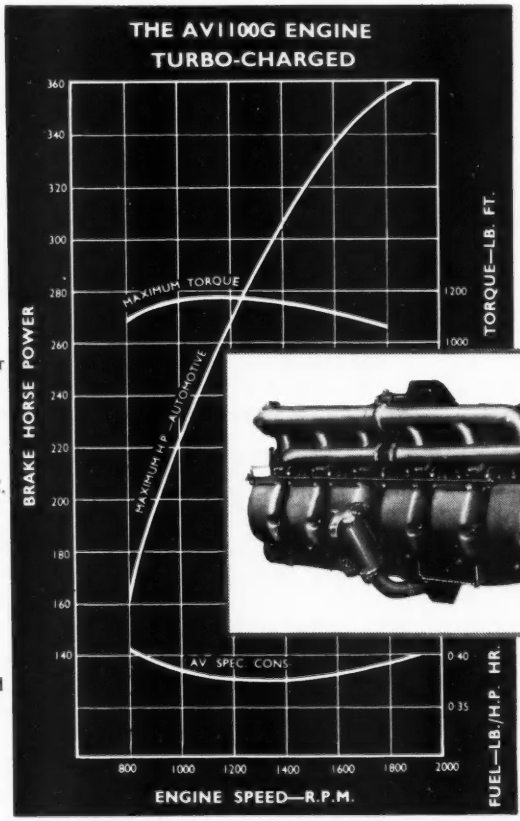

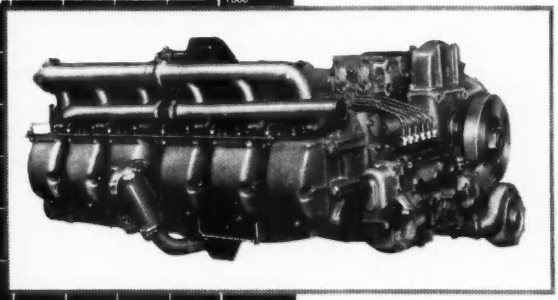

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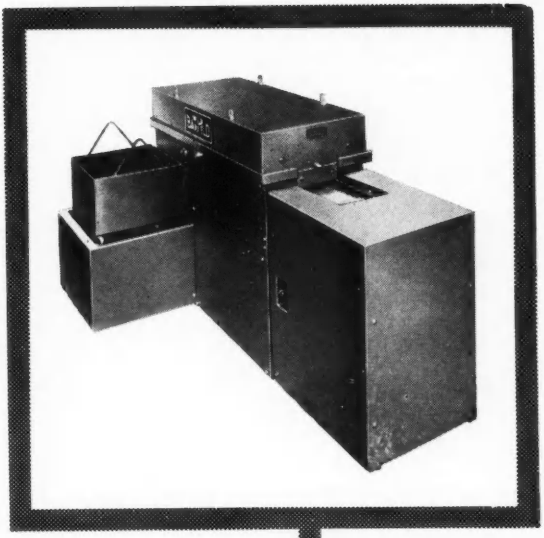

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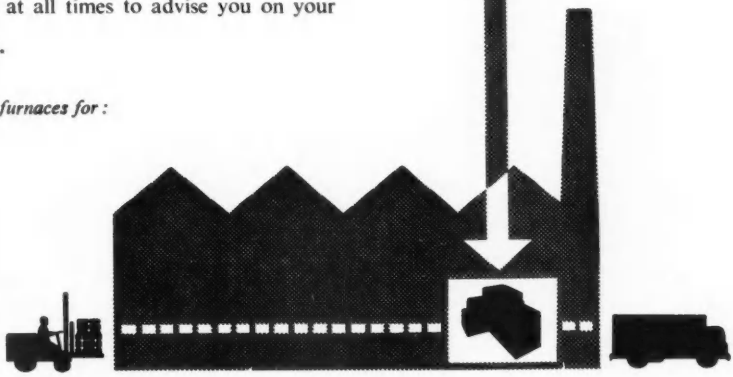

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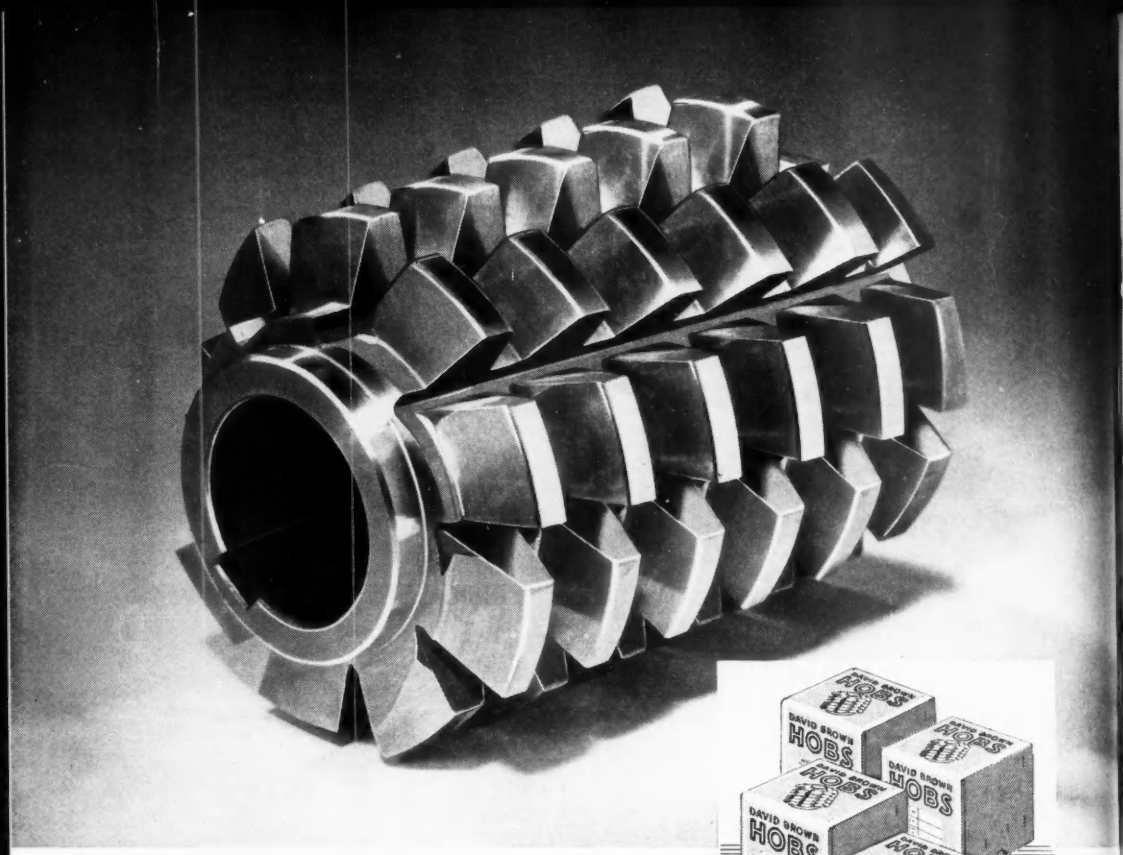

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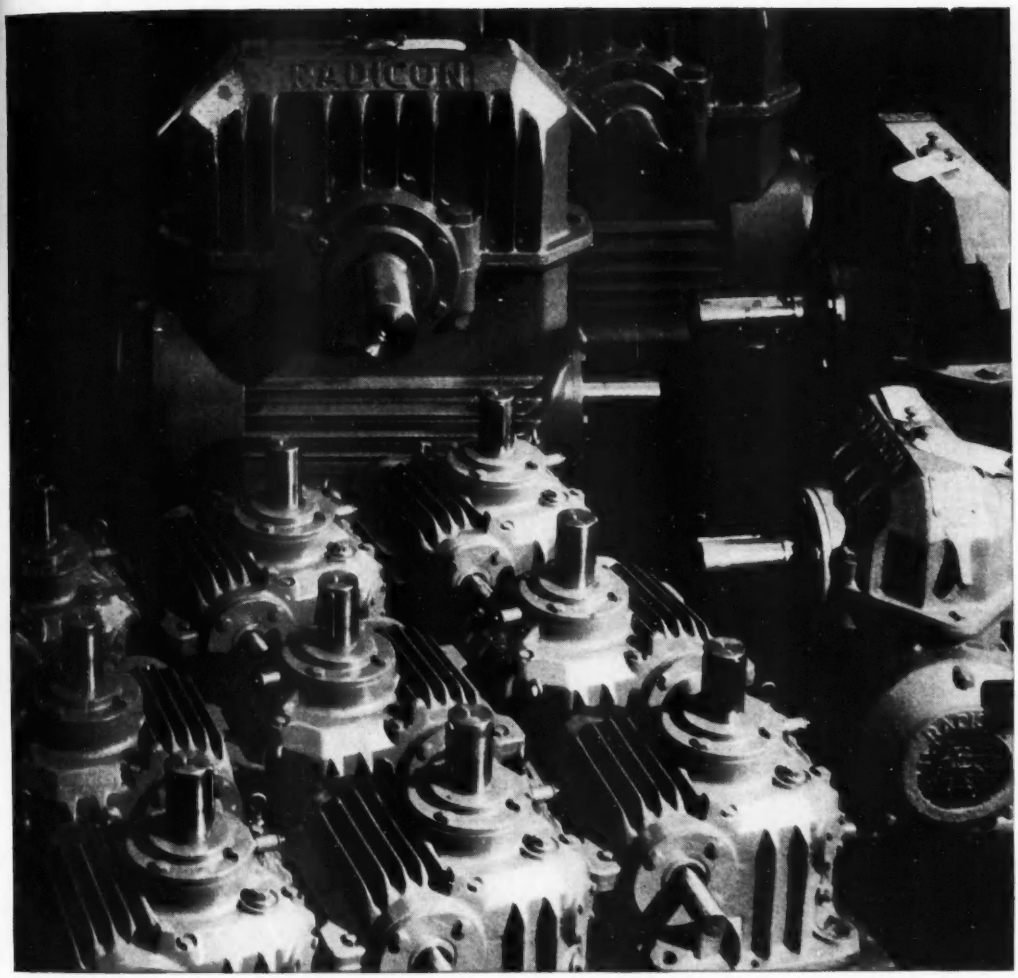

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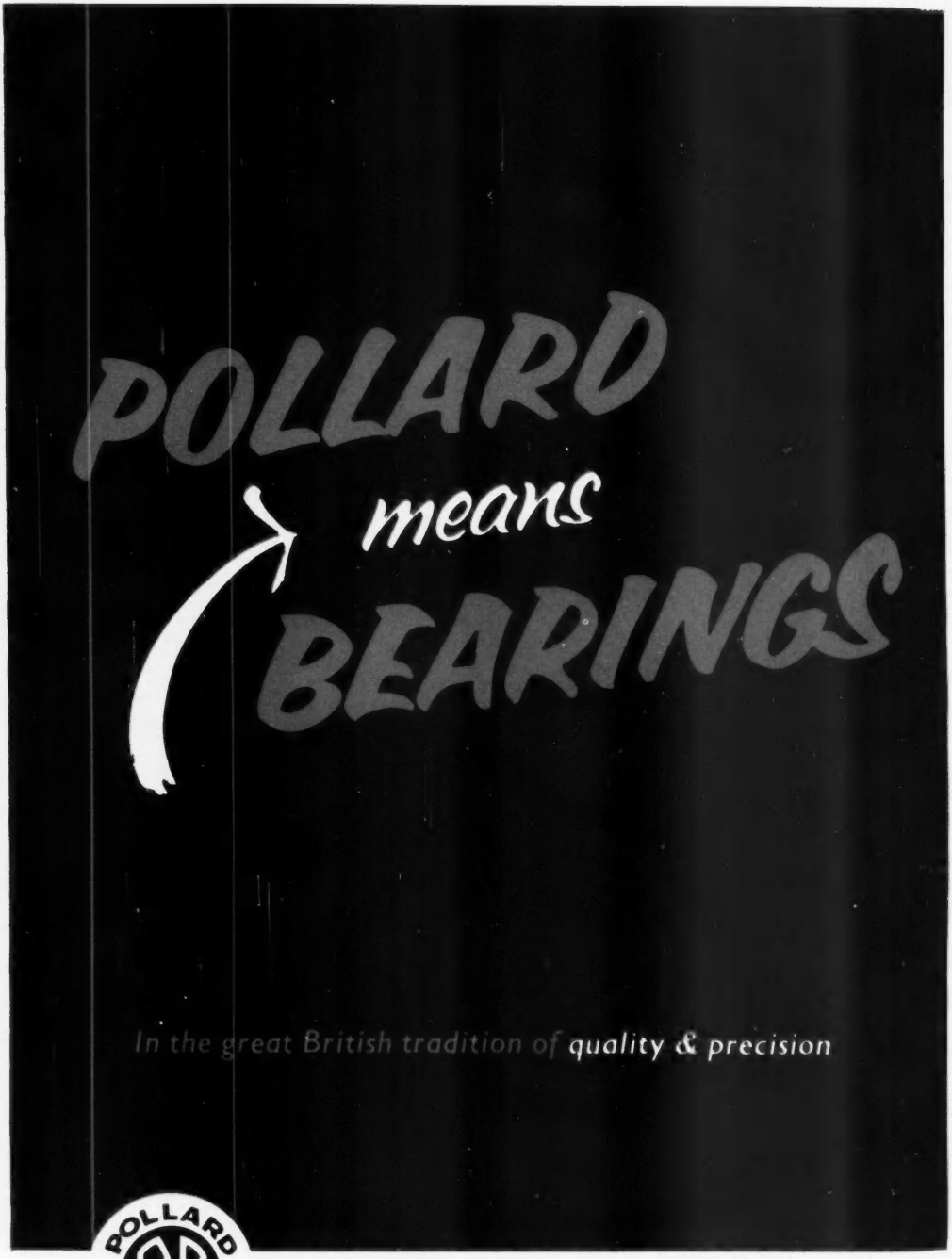
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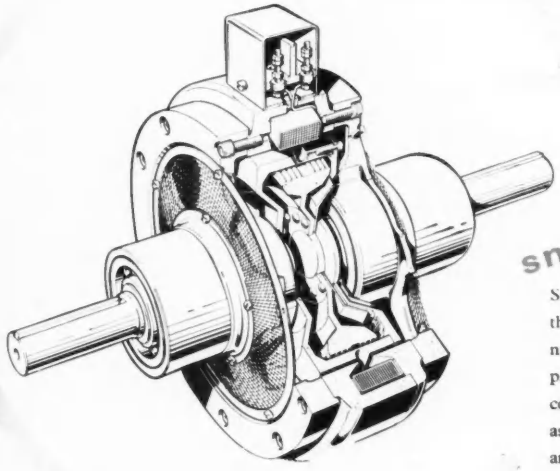

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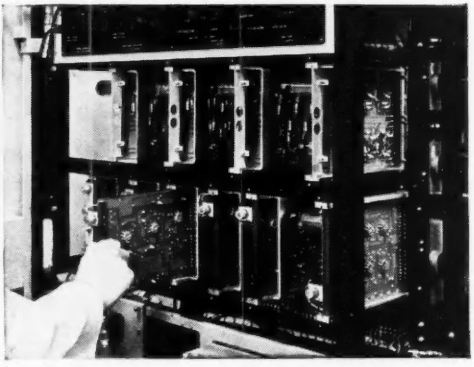
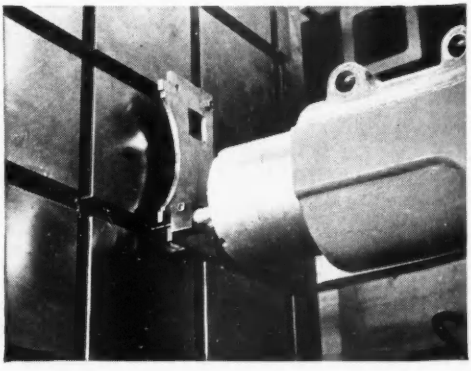
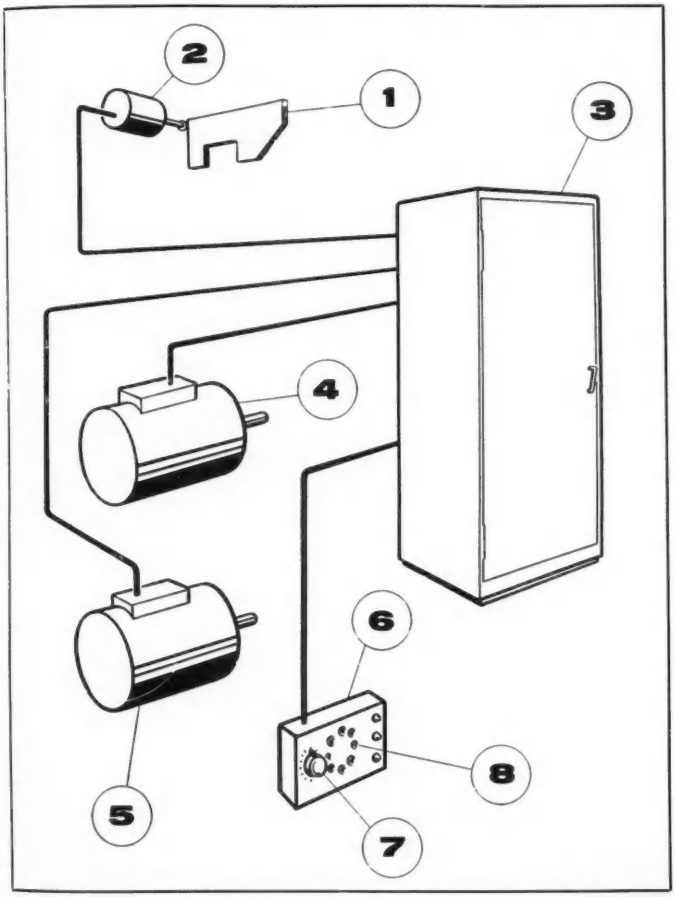


Exclusive printed circuit card unit construction brings simplification, standardisation and lower costs



Simple rugged tracer head has single moving part



1. template or model
2. tracer head
3. compact self-contained control cubicle
4. x.-axis high response servo motor of required rating
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In full scale production — hundreds in the field and four equipments a month going to one machine tool manufacturer alone — these equipments are so designed that they can be readily tailored to the requirements of any type of tool — from the largest to the smallest.

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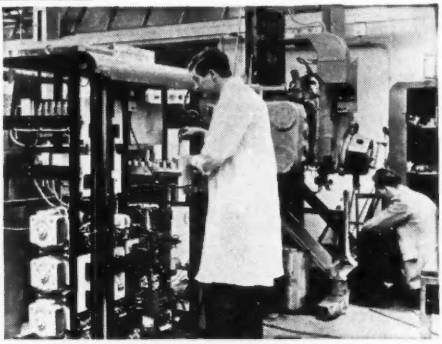
For more details write to Special Equipment Division at the address below.



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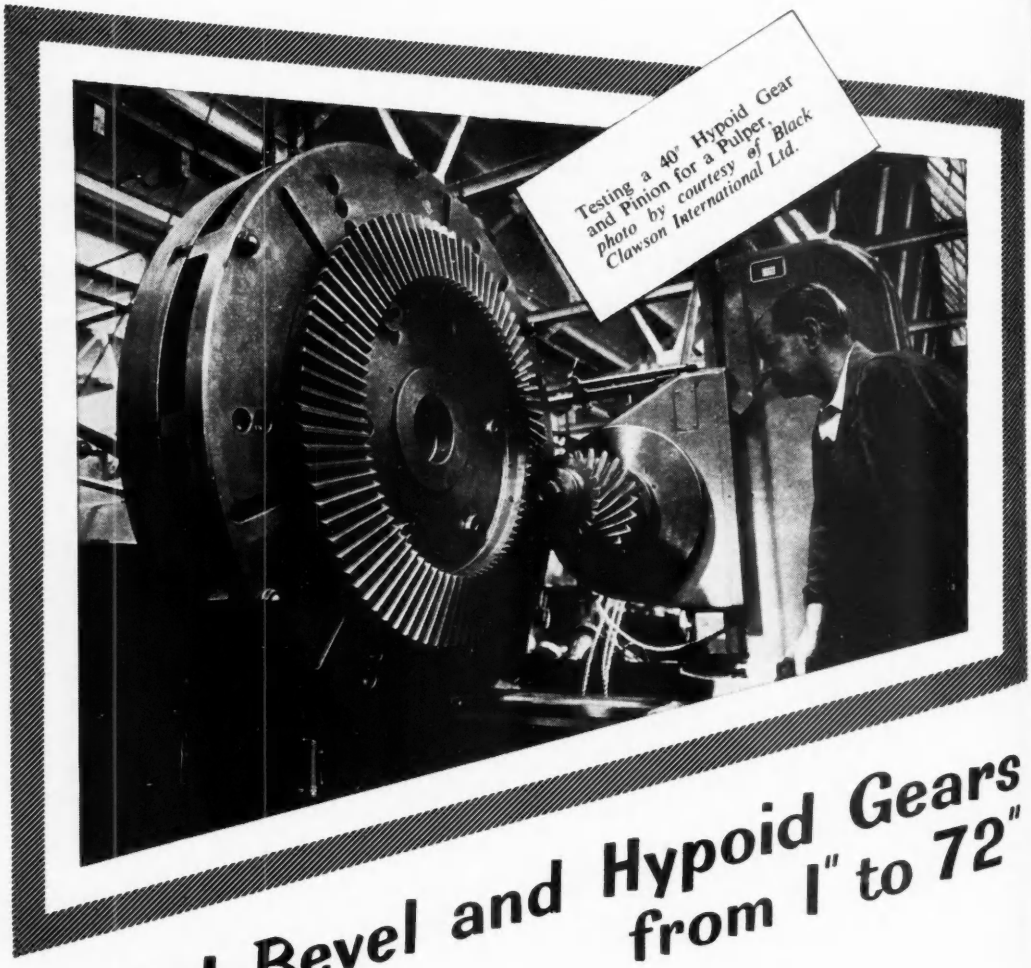

Testing a 40" Hypoid Gear and Pinion for a Pulper, photo by courtesy of Black Clawson International Ltd.

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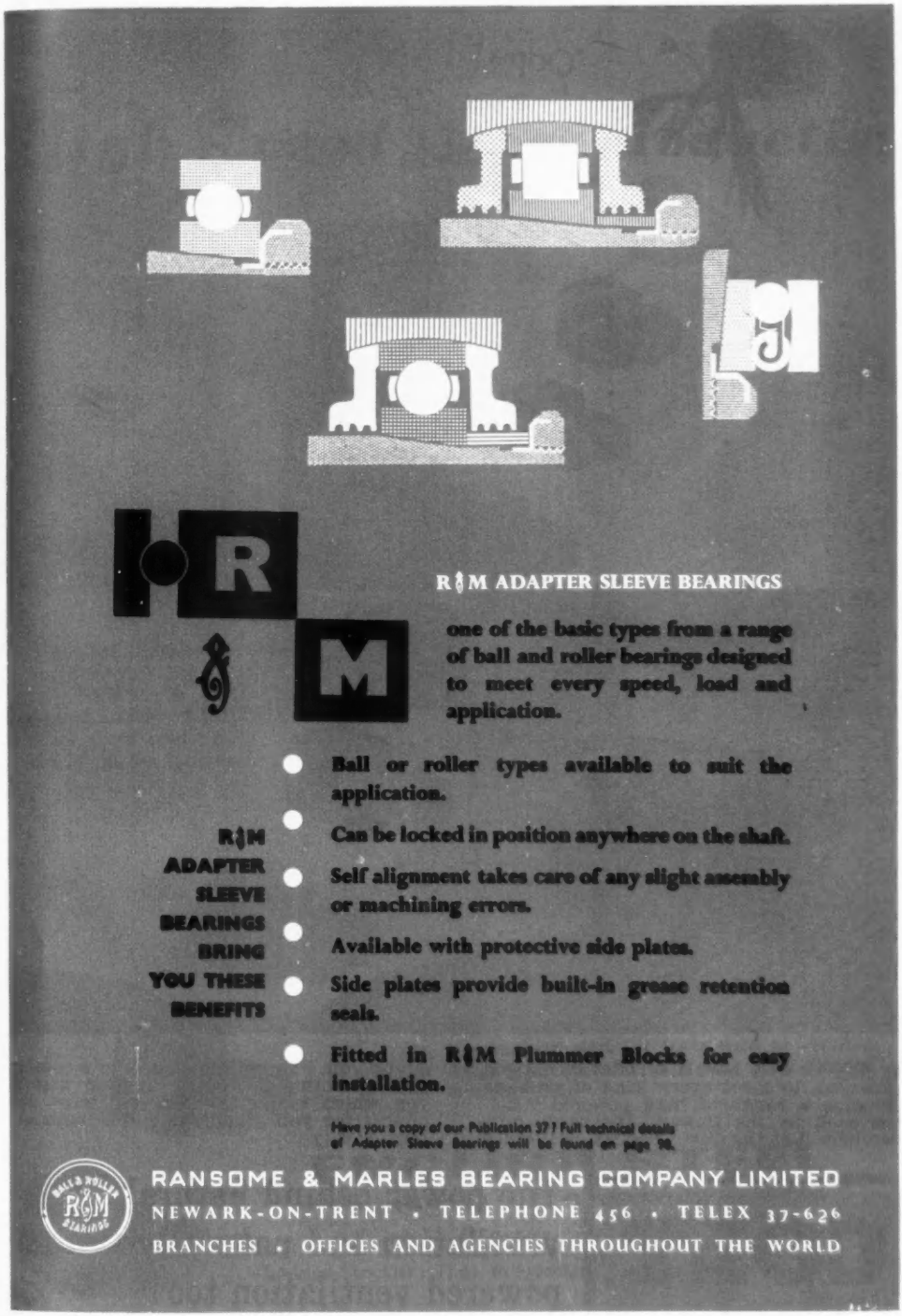
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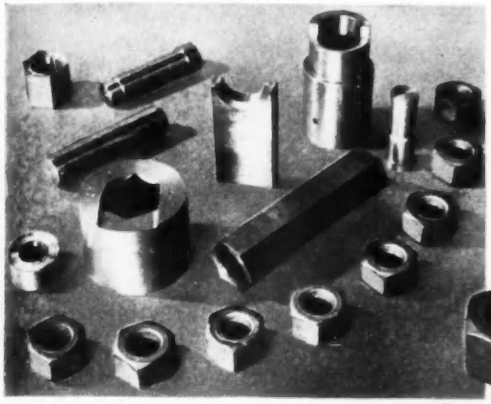

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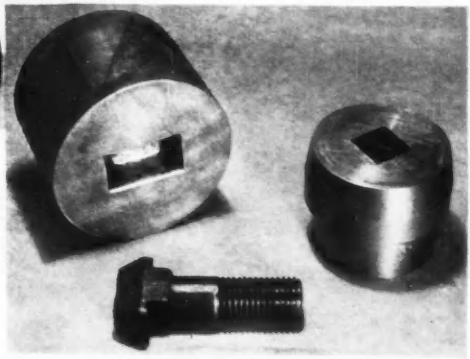

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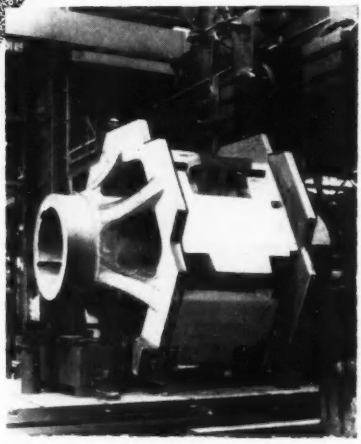

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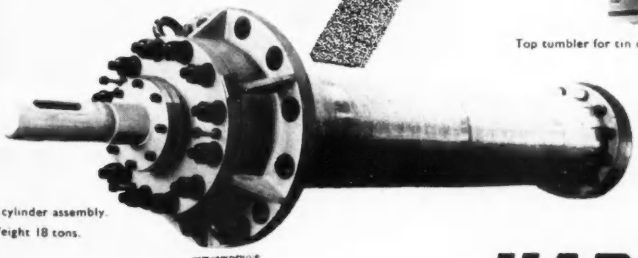

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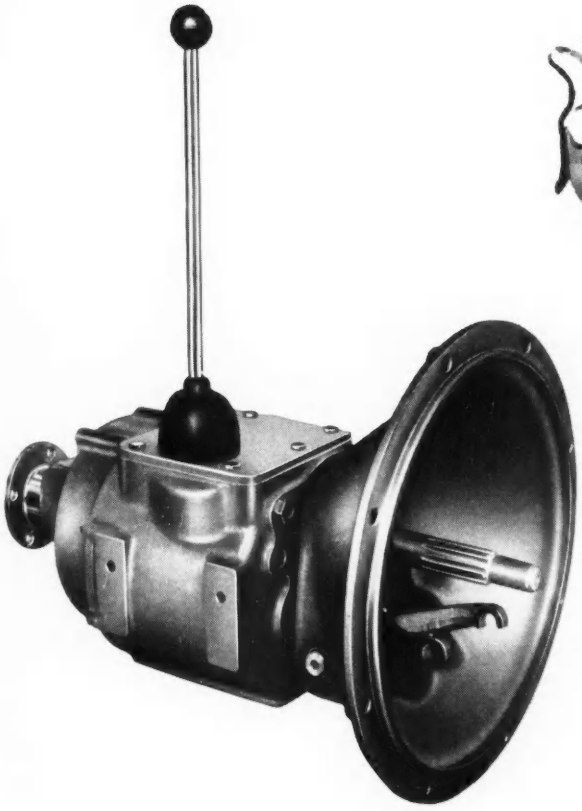

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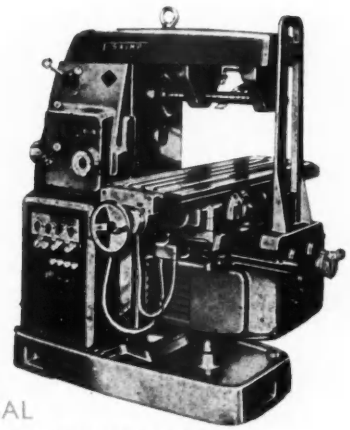

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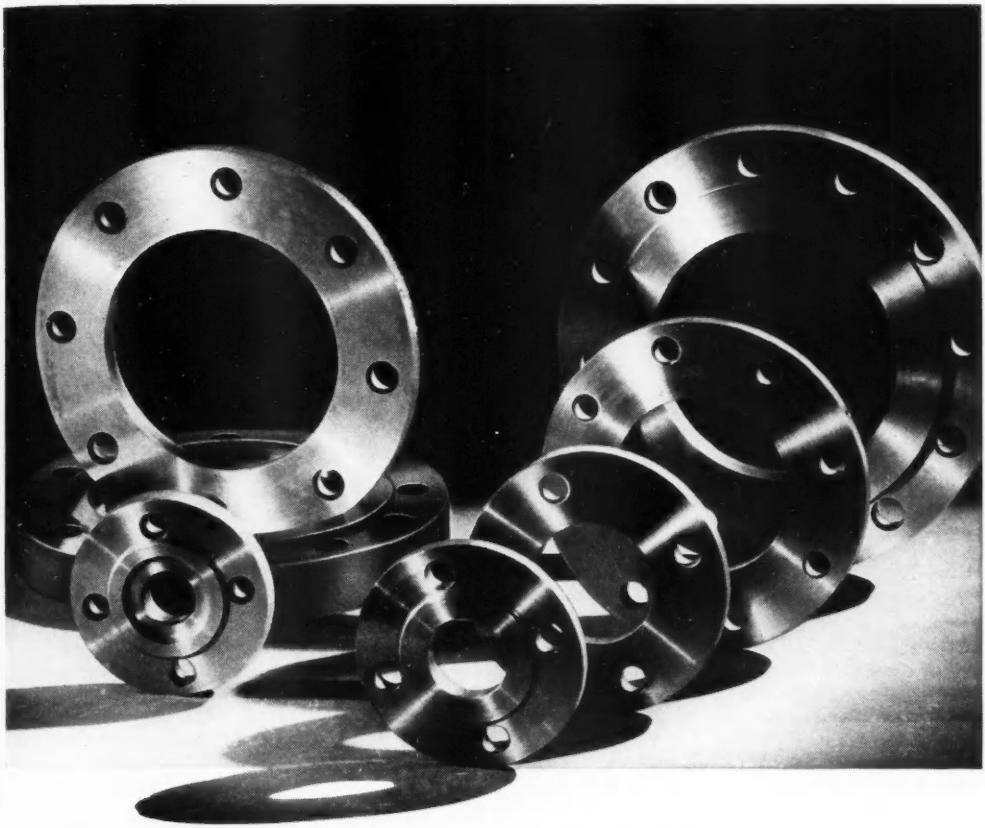

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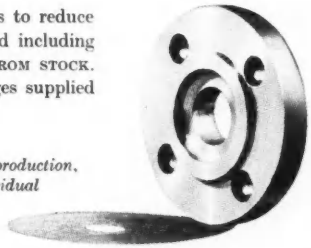

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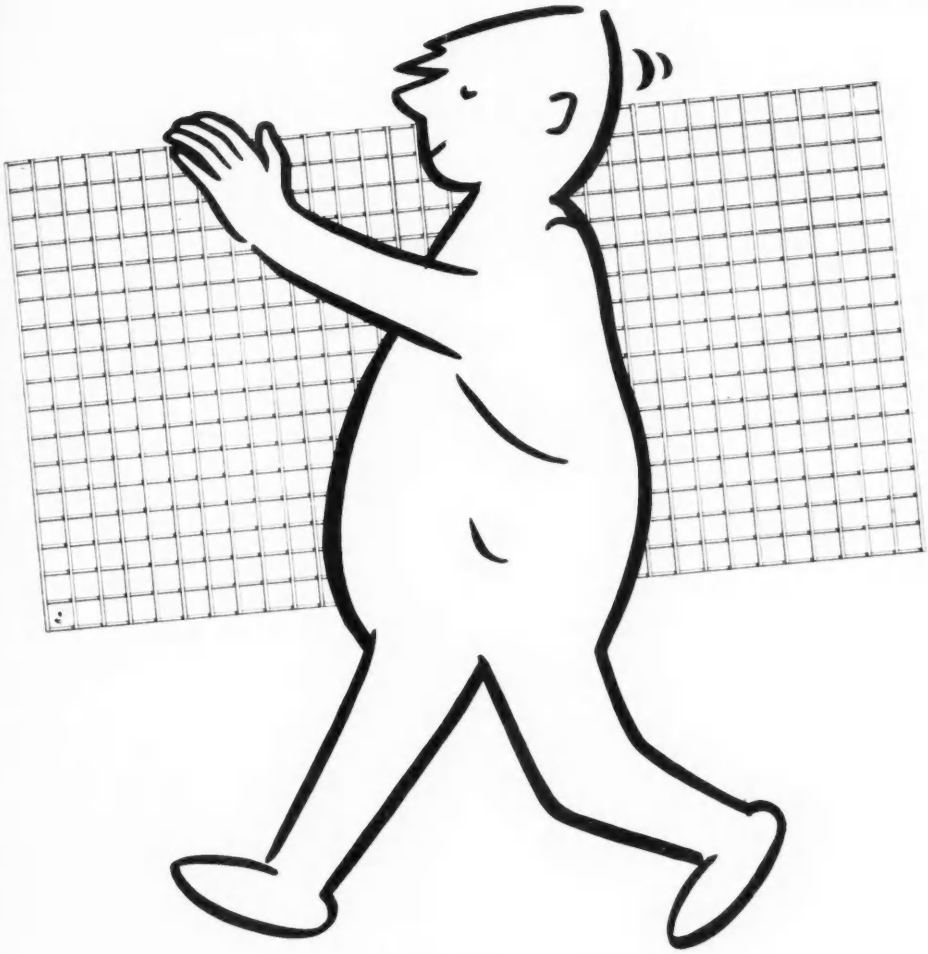

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THE B.R.C. ENGINEERING COMPANY, STAFFORD

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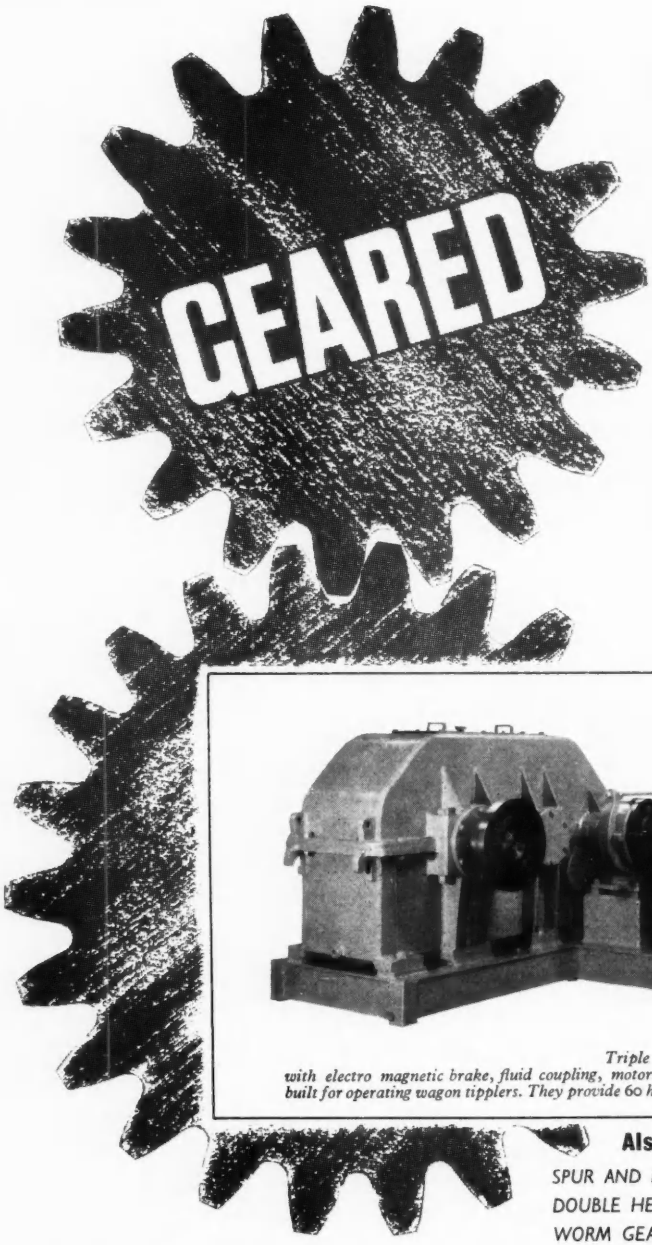
H-W 963

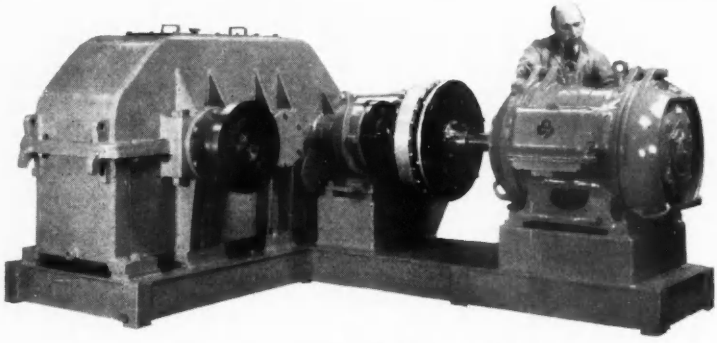


for the design and production of SPECIAL GEAR UNITS

Superb facilities are available at Angus Gear Division for the design and manufacture of gear units of all kinds to meet every industrial need.

An unusually complete service in this field, outstanding in its scope and quality, is the result of an accumulation of experience and valuable technical skill, allied to one of the most advanced gear cutting plants in Europe.

We shall be pleased to discuss your gear requirements



Triple reduction double helical gear unit, complete with electro magnetic brake, fluid coupling, motor and base plate — one of several such units built for operating wagon tipplers. They provide 60 h.p. at 750 r.p.m. and are splash lubricated.

Also in regular production are :

SPUR AND HELICAL GEARS up to 78" diameter.
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GEORGE ANGUS & Co LTD
GEAR DIVISION
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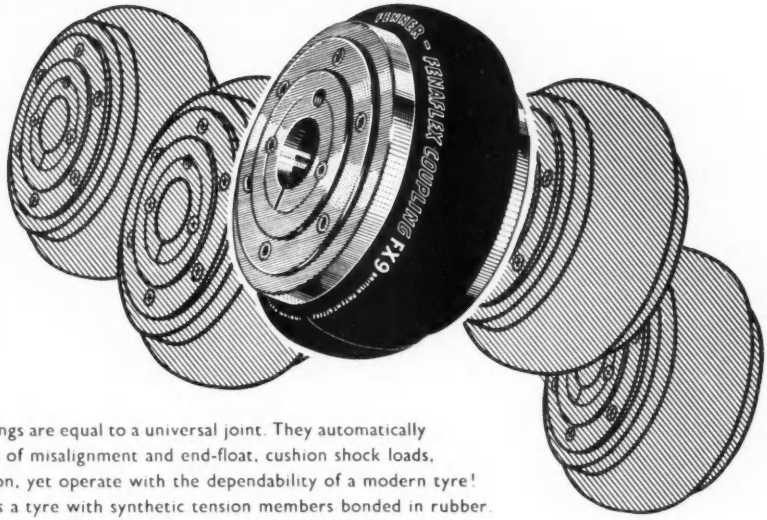
FENAFLEX

CUSHION COUPLINGS

THE RUBBER TYRE COUPLINGS WITH THE FOUR-WAY FLEX



Fenaflex Cushion Couplings are equal to a universal joint. They automatically correct *all* combinations of misalignment and end-float, cushion shock loads, reduce torsional vibration, yet operate with the dependability of a modern tyre! The Fenaflex Coupling *is* a tyre with synthetic tension members bonded in rubber. Depending on the size of the coupling and the duration of shaft misplacement, it corrects angular misalignment up to 4°, parallel misalignment up to $\frac{1}{8}$ inch and end-float up to $\frac{5}{16}$ inch. There is no metal-to-metal contact, lubricating is unnecessary and there are no protruding parts.

This coupling occupies the minimum space on the shaft and Fenner standard Taper-Lock bushes make mounting quick and easy. As the flexible member is moulded with a transverse split, it can be replaced without moving the machine or the motor. This flexible coupling with time-saving TAPER-LOCK for fixing, is available in 9 sizes, the largest taking 20 h.p. per 100 r.p.m.

Leaflet 353/18 will give you full technical information.

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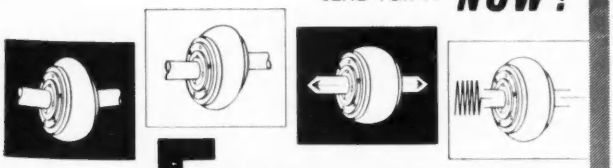

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Fenaflex Couplings are obtainable from stock at all 19 Fenner branches and Fenner engineers will gladly demonstrate Fenaflex to you—telephone your nearest branch.

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Have you tried Harris Tapping Lubricant ? Available in 2-oz (9d.), 7-lb (13/3) and 28-lb (47/-) packs.

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Vital links in controlled movement

A body needs muscles to control movement in very much the same way as a mechanism needs springs. These vital links take the stress and strain of every day rigorous use — nature provides the muscles . . . SALTER provides the springs. Two centuries of experience and development in the manufacture of springs of every type have enabled us to keep ahead of the ever-changing requirements of industry.

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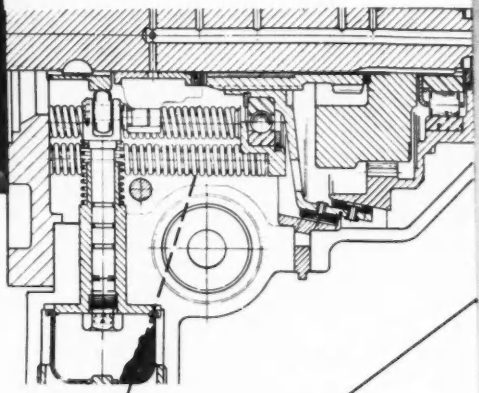

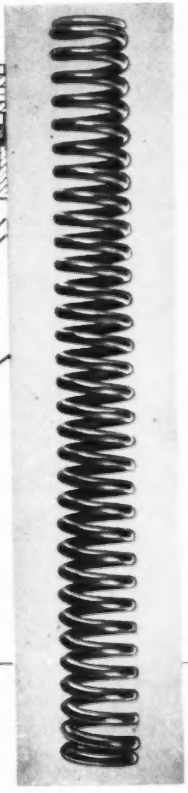

For springs with the highest reputation and top performance specify SALTER all-action springs.

The applications for SALTER springs are wide and varied — from heavy machinery to finely balanced instruments.

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F-L-E-X-I-B-I-L-I-T-Y *WINS!*

With Brown Fintube sectional heat exchangers existing units can be regrouped to cater for changes in plant process requirements . . .

AT ALMOST NO COST

Photo shows Brown Fintube Sectional Heat Exchangers supplied to Messrs. Peter Brotherhood Ltd., Peterborough

HIGH PRESSURE FINTUBE UNITS

Equally easy to handle but will withstand pressures of over 10,000 p.s.i.

As makers of the finest heat exchange unit—BROWN FINTUBES—we are specialists in heat exchange problems. Tell us your needs and we will supply the answer. When we DESIGN something we GUARANTEE performance.

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New AEI Single-Operator A.C. Arc Welding Sets

The latest 'Thermac' a.c. hand-welding sets incorporate improved design features which provide greater mobility and ease of operation. They require practically no maintenance. Both models comply with B.S. 638/1954.

ALTERNATIVE RATINGS
Model 185799 has a continuous hand welding current range of 50-250 amps, with a maximum intermittent current of 333 amps.
The larger set, model 185800, has a current range of 75-350 amps, with a maximum intermittent current of 450 amps.

SMOOTH CONTROL
The moving-coil regulator gives infinitely variable adjustment of welding current over the whole range without the use of tappings.

SAFETY
Sets are air cooled, making fire risk negligible.

EASE OF ACCESS
All working parts are easily accessible.

Please write for descriptive leaflet 783/17-1 to your local AEI office or to:—

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TRANSFORMER DIVISION - Heating & Welding Department

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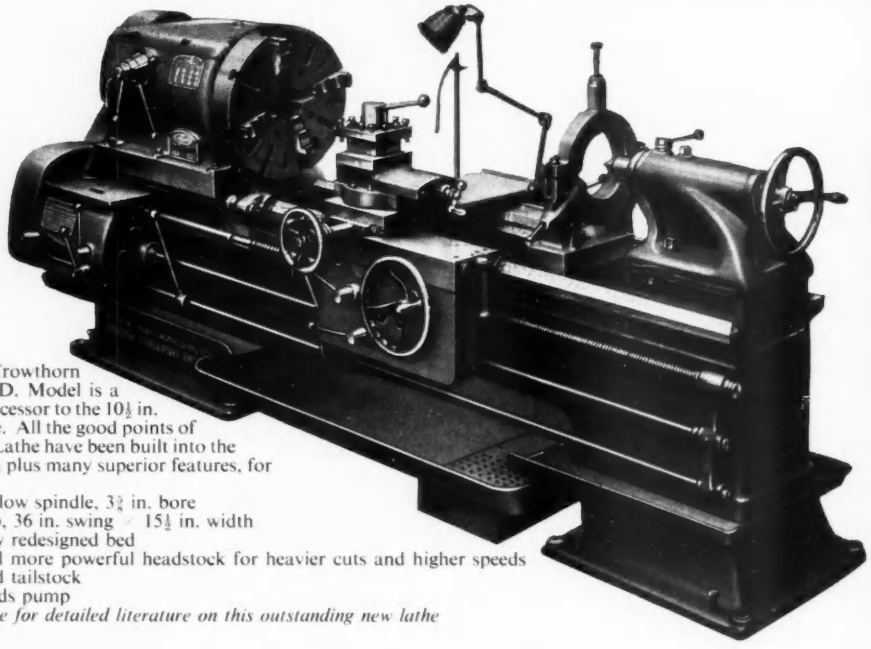
the new

CROWTHORN

10½" (21" SWING) H.D. MODEL CENTRE LATHE



The new Crowthorn 10½ in. H.D. Model is a worthy successor to the 10½ in. M.D. lathe. All the good points of the M.D. Lathe have been built into the new design plus many superior features, for example :

Larger hollow spindle, 3⅜ in. bore
Larger gap, 36 in. swing × 15½ in. width
Completely redesigned bed
Larger and more powerful headstock for heavier cuts and higher speeds
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Electric suds pump

Please write for detailed literature on this outstanding new lathe

Over fifty years of high class machine tool manufacture

Other famous models in the Crowthorn range include Centre Lathes from 7½ in. to 20 in. centres, 30 in. and 36 in. swing Boring and Facing Lathes with square or hexagon turrets, combination Turret Lathes and 19½ in. stroke Shaping Machines.

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REDDISH - STOCKPORT - ENGLAND
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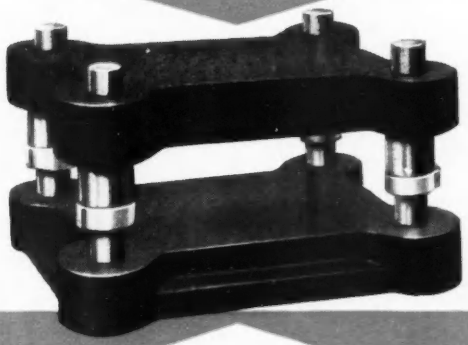
CROWTHORN
HIGH CLASS MACHINE TOOL MAKERS

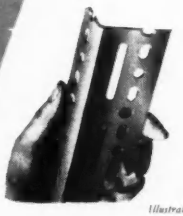
CL.96

Are YOU tooling-up for long runs?



K E 970

2% CARBON 14% CHROME HIGH DUTY TOOL STEEL



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for the dies and punches to produce their famous slotted angle. Millions of slots have been punched with the minimum amount of tool regrinds.

Illustration by courtesy of MESSRS. DEXION LIMITED.

May we tell you more about the properties of K.E. 970 and other K.E. tool steels? The booklet shown below is available on request, free of charge.

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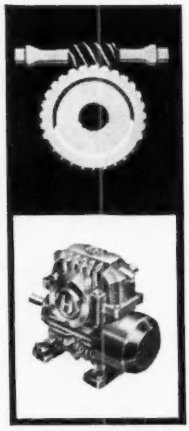

say
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first for
worm gears
and gearboxes

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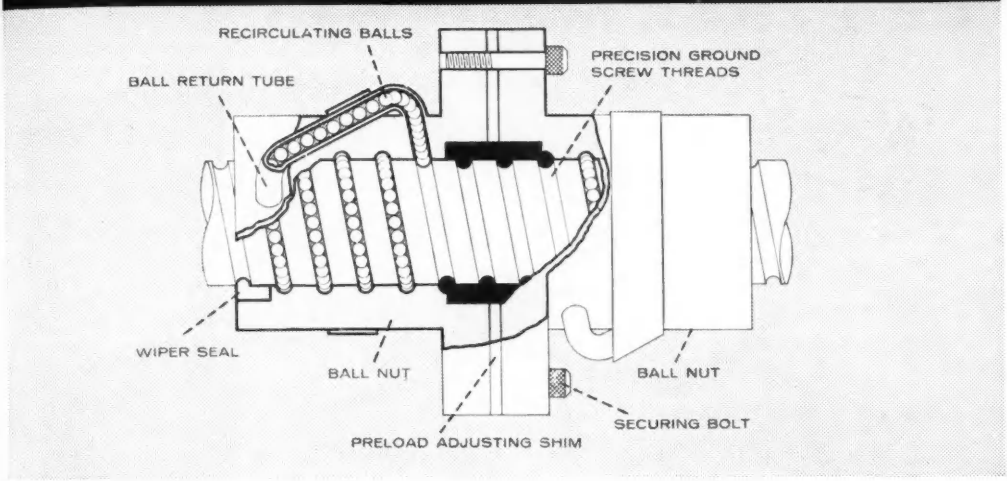
MILNROW • LANCASHIRE

If there were a Holroyd motto, it would be 'do it ourselves'. Almost 100 years' experience in machine tool and gear production has enabled us to build up a sound technique for manufacturing worm gears. Nearly all the operations of manufacture and inspection—of both gears and cases—are carried out by methods of our own. (We say 'nearly' all because if we come across a machine or process we think might help us, we don't hesitate to snap it up!) And we don't believe in making things in dribs and drabs, so we always have a fine stock of standard worm gears and gear units. This helps to keep prices low and delivery quick. We also do a lively business in spur, helical, and bevel gears; special machine tools; helical rotors for compressors, meters, and pumps; rotor manufacturing equipment; rotor timing gears; and Holfos centrifugal castings and bushes. We use centrifugally cast Holfos Phosphor Bronze—a material of our own development—for all our gear wheels. It was used in the Holroyd worm gear which set up the World Record—still unbeaten!—on the Daimler-Lanchester Worm Gear Dynamometer at the N.P.L. in 1931.

CRC/B2

Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90%, and they can operate within a temperature range of -52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increements of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

**Complete technical and manufacturing co-operation with Beaver Precision Products Inc, Detroit.*

For further information please write to:
J. B. STARKY, SALES MANAGER (BEAVER PRODUCTS DIVISION), BRISTOL SIDDELEY ENGINES LIMITED
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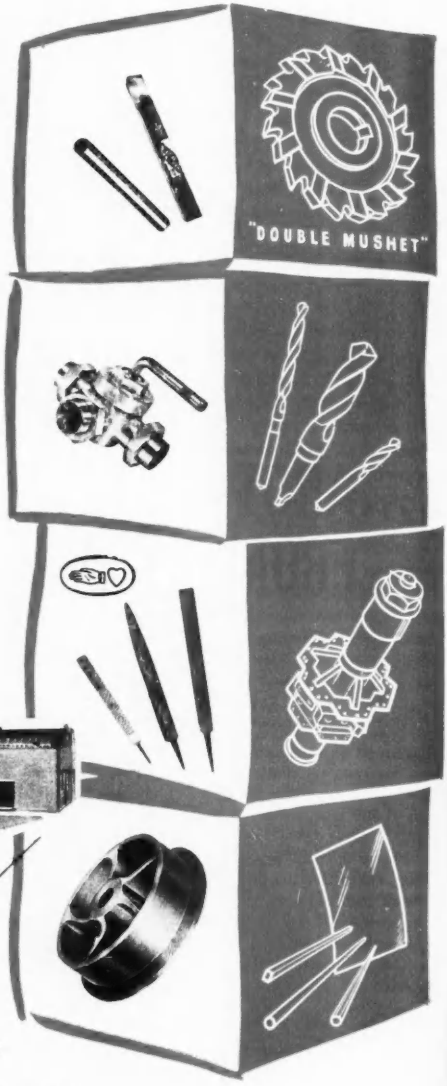
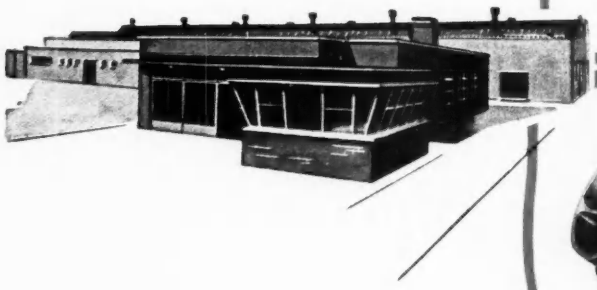
Integrated experience from over a century of craftsmanship has made the name of *Osborn* world-famous as a hallmark of quality in the manufacture of fine steels and steel products.

Products in alloy, stainless and tool steels are manufactured throughout within the same organisation, and include castings by general foundry and precision methods, forgings and engineers' cutting tools.





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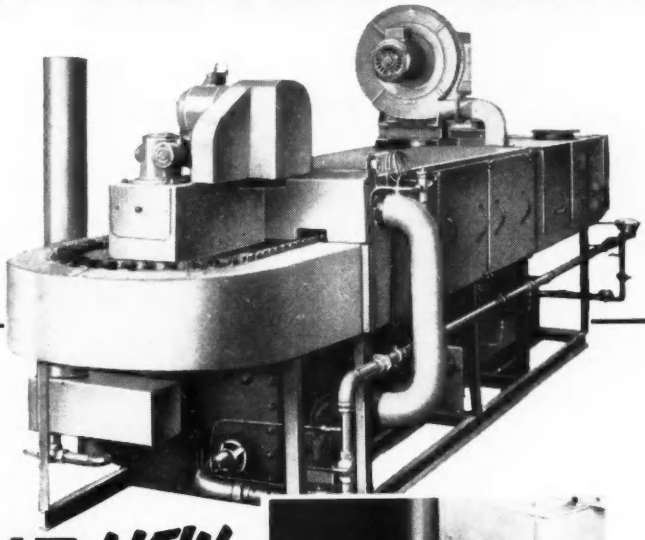
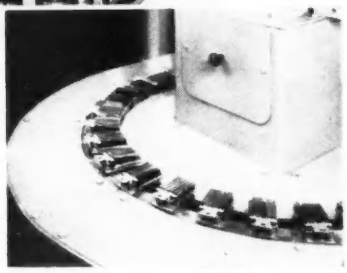
CLYDE STEEL WORKS, SHEFFIELD

Right on the chin!



Washing THE NEW REMINGTON ELECTRIC SHAVER HEADS prior to plating



Immediately prior to plating, the New Remington shaver heads are passed through this Dawson machine to remove lapping compound. They are subjected to intense, prolonged jetting treatment to bring them to the highest possible standard of cleanliness followed by a hot air drying treatment. 40,000 shaver heads are handled on each machine in an eight-hour day.
This is just one more example of the vast range of jobs tackled by Dawson equipment. So whatever your metal cleaning problem get in touch with Drummond-Asquith Limited, at the address below and we will endeavour to arrive at a solution both efficient and economical.

Dawson **DEGREASING AND CLEANING PLANT**

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model 1400

8 in. by 24 in. capacity

This is a new Surface Grinder having all the best features of our smaller, world-renowned "Model 540" but also including many others which are necessary for this larger capacity machine. It is a high quality machine and most suitable for use in the Toolroom particularly for form grinding.

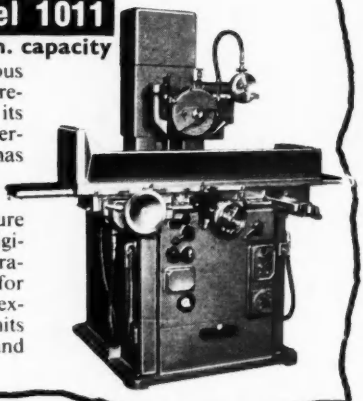
FAMOUS SURFACE GRINDERS

JONES & SHIPMAN

model 1011

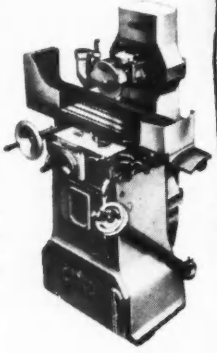
12 in. by 27 in. capacity

This is the famous "Model 1011" renowned for its high quality performance. It has many features incorporated in its design to ensure the necessary rigidity and operational control for grinding to extremely fine limits of accuracy and finish.



6 in. by 18 in. capacity

The Model 540 is a unique machine which has all the essential qualities for high class surface grinding. It is without doubt the best known machine of its kind in the world, thousands are in use giving first class performance and trouble-free service.



model 540

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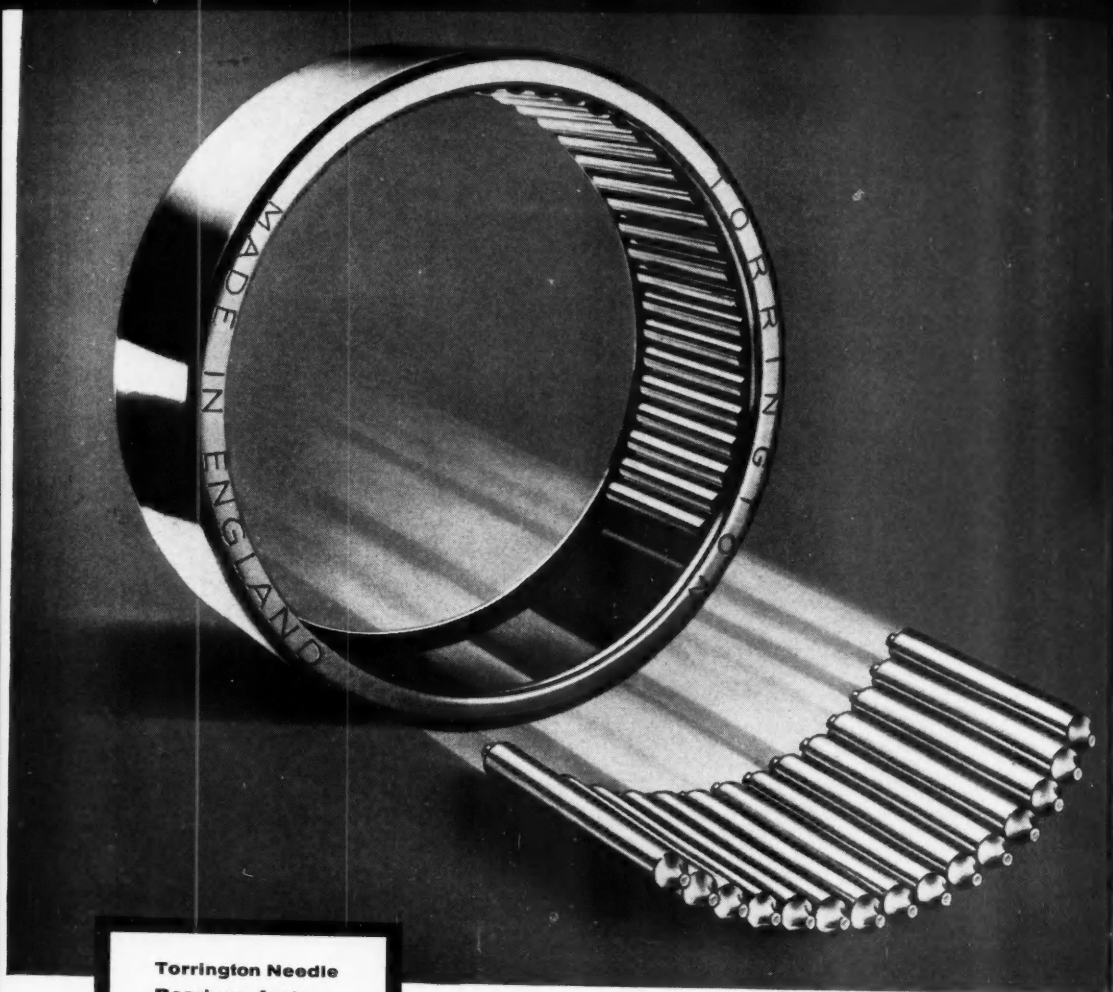
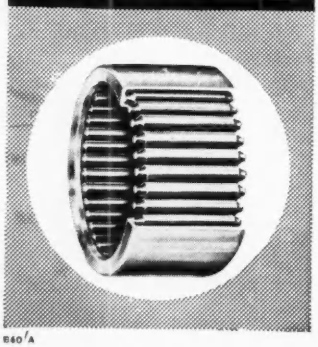


Torrington Needle Bearings feature:

* *high radial load capacity*
* *low coefficient of starting and running friction*
* *low unit cost*
* *long service life*



B40/A

This is why Torrington Needle Bearings provide maximum radial load capacity

The Torrington Needle Bearing's full complement of small diameter rollers provides the largest possible number of bearing contact lines in the load zone. This gives Needle Bearings a higher radial load capacity than any other bearing of comparable size.

Precision rollers ensure smooth anti-friction performance with low coefficient of starting and running friction to match this unequalled capacity. Rollers are positively retained by the turned-in lips of the outer shell, permitting simple, economical installation and assembly.

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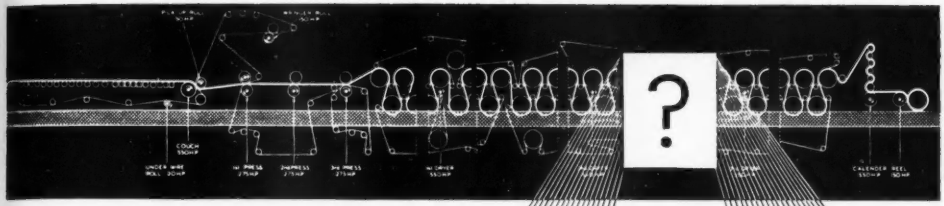

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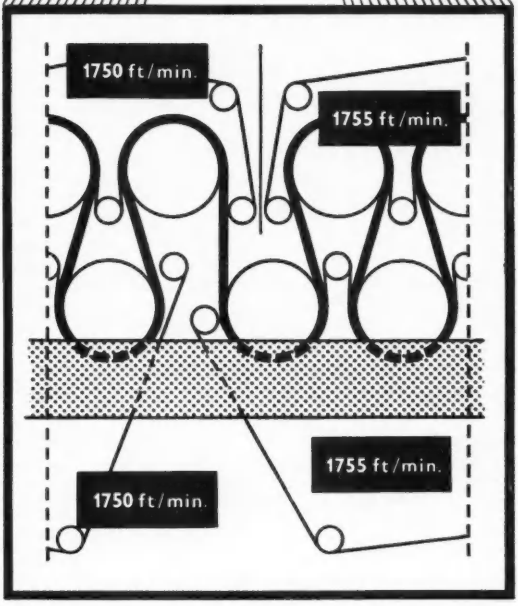
The importance of accurate differential speeds in sectional paper machine drives is one of the many specialised industrial problems of which AEI has extensive practical knowledge.



... call in an AEI sales engineer

who specialises in your industry. He understands your particular problems and will ensure that you get drives and control gear designed to meet your exact needs. But his services go far beyond the supply of equipment. He will assist with every aspect of the problem, including layout, integration of related equipment, safety and operational considerations.

AEI **Associated Electrical Industries Limited**

Motor and Control Gear Division

RUGBY & MANCHESTER, ENGLAND

INCORPORATING THE MOTOR AND CONTROL GEAR INTERESTS OF BTH AND M-V

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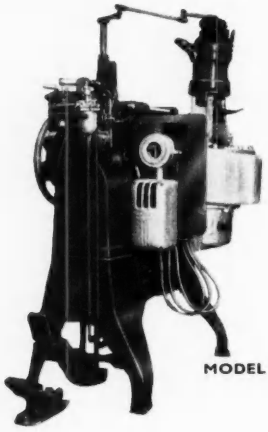

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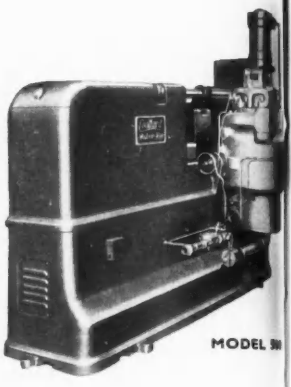
with production improvement
means business for you



MODEL 3H

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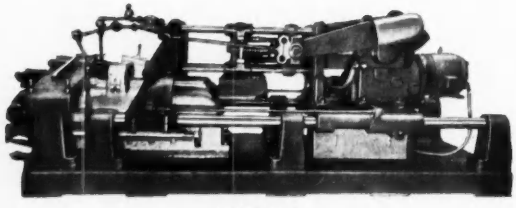

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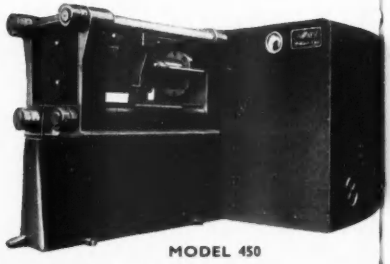

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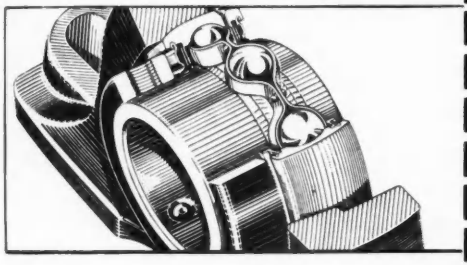

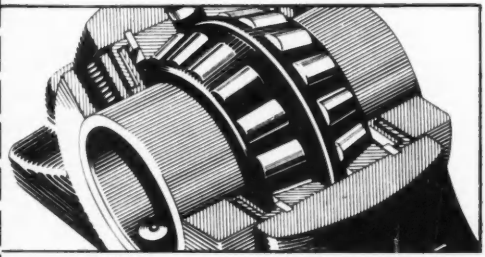

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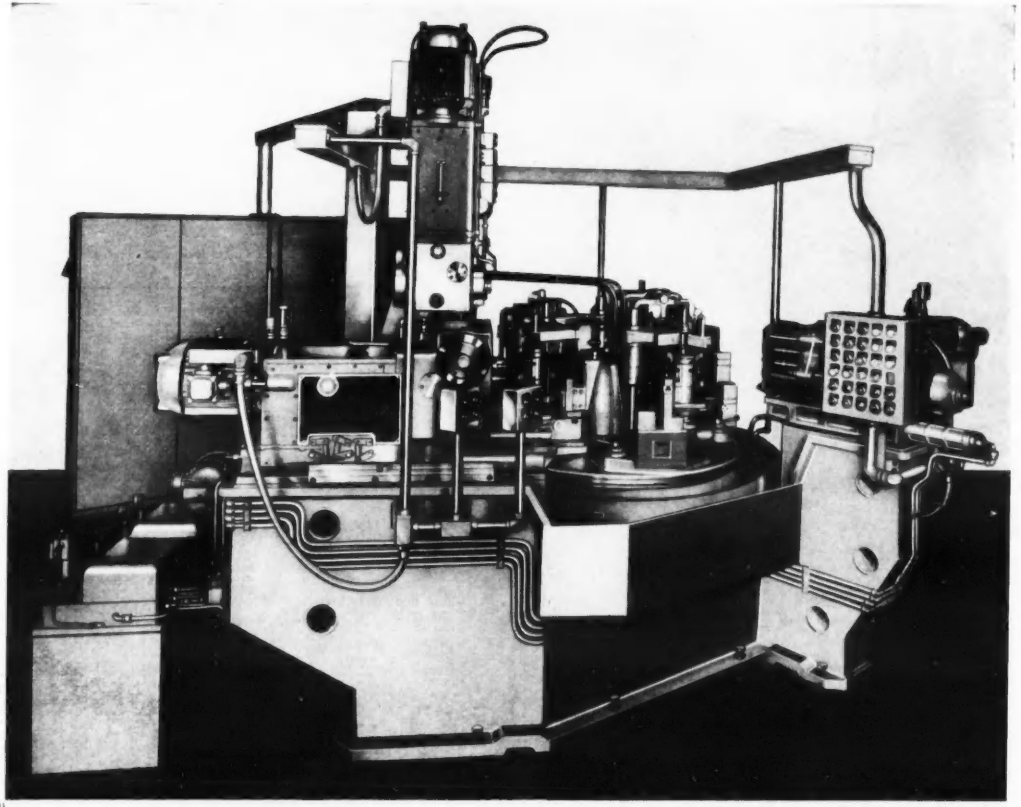

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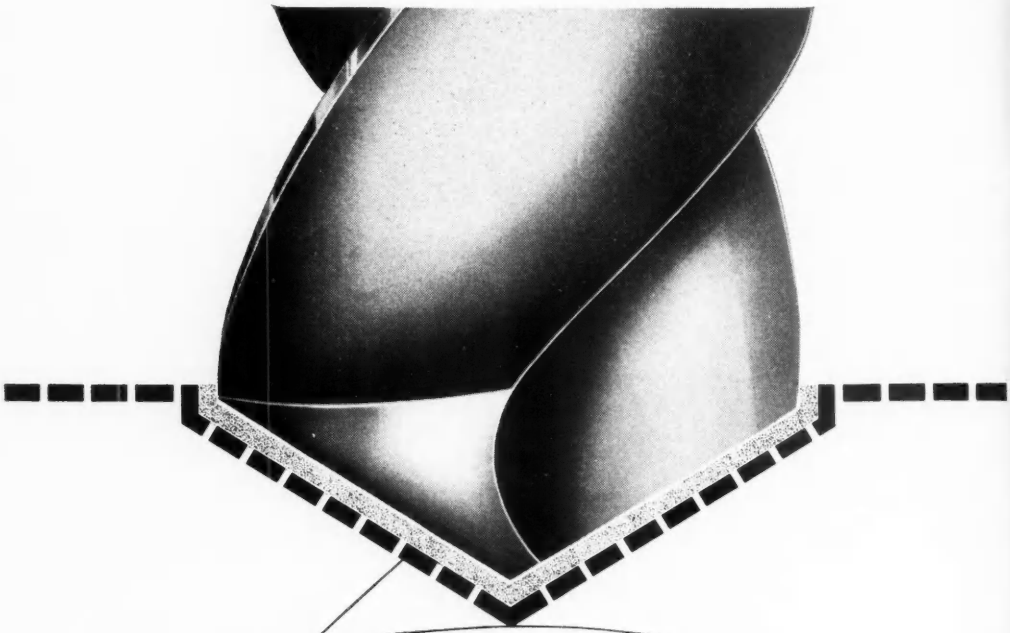

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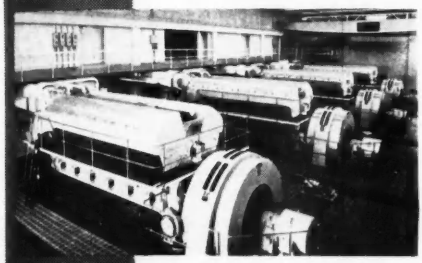

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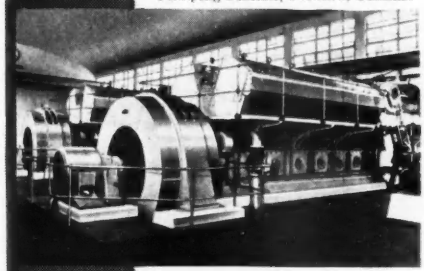

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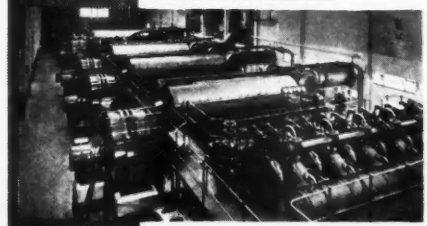

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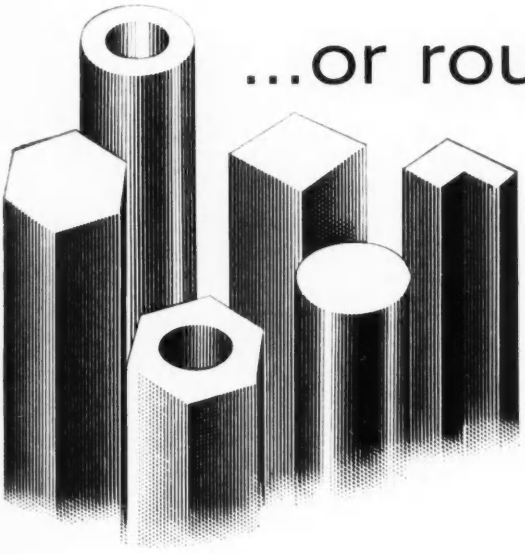

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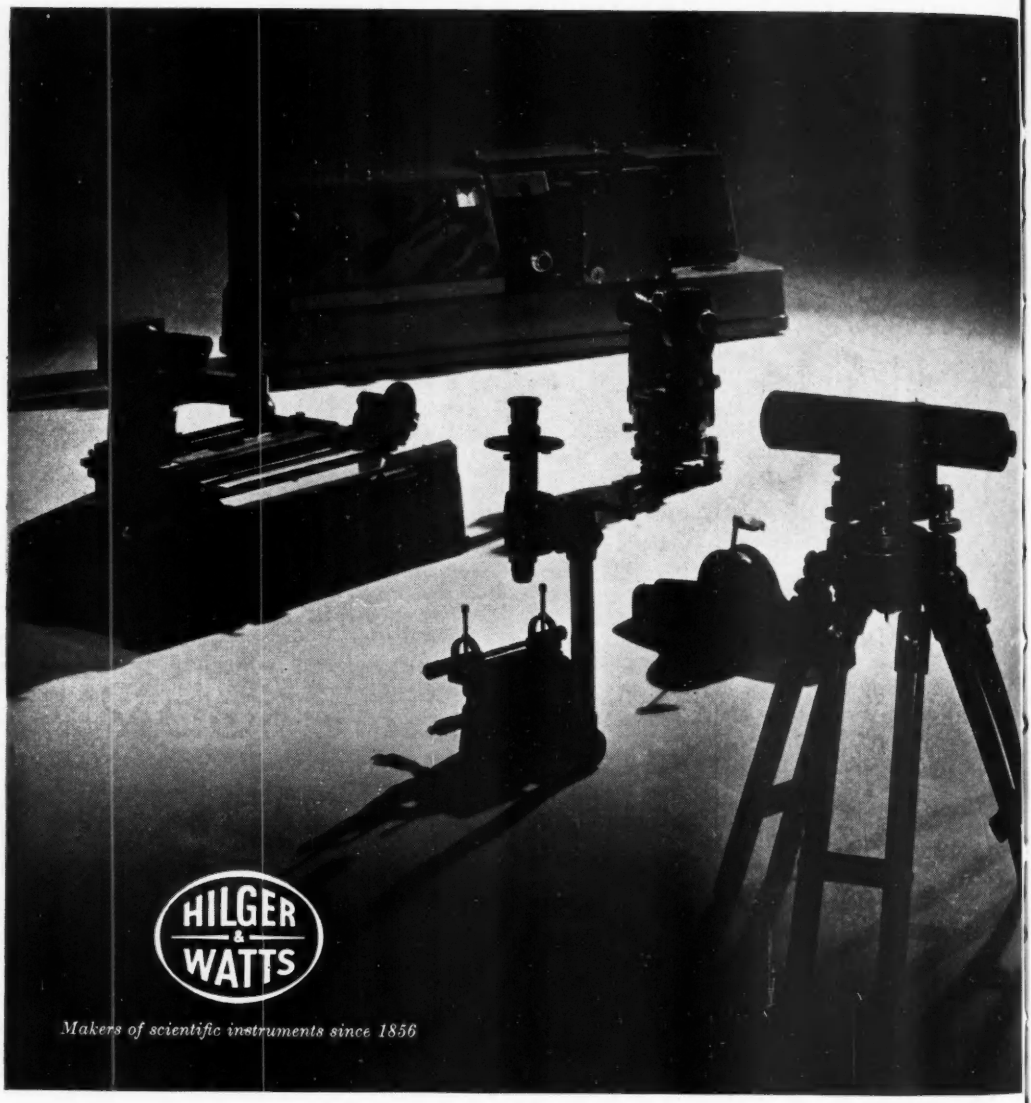

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●*PHOTO-ELECTRIC CALIBRATION OF ELECTRICITY METERS*

In this new photo-electric calibrating and testing instrument for electricity meters, two electric pulse trains are derived by reflecting light beams from the rotating armatures of a meter under test and of a standard meter onto photoelectric devices. The parts of the armatures from which the light is reflected are so constructed that the light beams are interrupted at regular intervals, recurring in each case at a frequency depending on the speed of rotation of the armature. The impulse train derived from one armature is applied to a cathode-ray tube as a signal voltage, and the impulse train derived from the other armature is applied to a sweep generator capable of being synchronized by an impulse train having a repetition frequency of any value within the entire range of frequencies produced in operation. In this way a sweep voltage, or voltages of the same frequency, are applied to the cathode-ray tube to produce a regularly recurring trace.

The instrument may, for instance, be so designed that the impulse train derived from the one armature is applied across one pair of deflection plates of the cathode-ray tube, and the impulse train derived from the other armature is applied to a relaxation oscillator comprising a capacitor. This capacitor is arranged to be charged through a constant-current pentode valve, and discharged on the application of each impulse. The current supplied by the pentode valve is regulated by a feedback circuit in such a way that any tendency for the sweep-voltage amplitude to vary is resisted. This method is claimed to be particularly advantageous when successively calibrating meters having different rated loads.

From *Brit. Pat. Spec.* 819, 136,
Landis & Gyr A.G., Zug, Switzerland.

● *ELECTRIFIED FIBROUS AIR FILTERS*

There are two principal methods of separating suspended particles from air, i.e., mechanical separation and electrostatic precipitation. Mechanical separation includes dry-type filters, cyclones, water scrubbers, and gravity settling chambers. Mechanical separators depend on inherent differences in size and density existing between particles and the gas containing them. In contrast, electrostatic precipitators cause a difference between properties of the particles and those of the gaseous medium, either by charging the particles in an ionizer or, without an ionizer, by subjecting them to polarization in the field existing between charged plates of the precipitator. The principal mechanism of removal in mechanical separators is inertial impingement, this being effected by turning the direction of the air stream, and thus causing particles to be thrown out by their inertia onto collecting surfaces. As it is necessary to exert force on the entire air stream, the operation causes a pressure drop which increases with separation efficiency.

Electrostatic precipitators do not suffer from this defect, since the applied field acts directly on the particles alone, so that they have the inherent advantage of high efficiency at a very low pressure drop. Unfortunately, ordinary electrostatic precipitators are not satisfactory where space requirements must be kept low. However, by inserting fibre-glass in the inter-space between the plates of an electrostatic precipitator, an electrified fibrous air filter can be obtained. Owing to the fibre-glass packing the particles passing into the filter have only a few thousandths of an inch to travel under the influence of the electric field before contacting a collecting surface, and a very high collecting efficiency can therefore be obtained within a minimum of space.

From *Applications and Industry* (AIEE), U.S.A.,
November 1959, pp. 276–278.

● *HEAT TRANSFER IN THE PRESENCE OF A MAGNETIC FIELD*

In a gas heated to a very high temperature, ions and free electrons are present which cause it to become electrically conductive in the same way as a molten metal. It is well known that flowing streams of such conductors are affected by electrical and magnetic fields. Two important modes of heat transfer of fluid flow are those of forced and free convection. A recent analysis of the heat transfer in laminar forced convection flow of an electrically conductive fluid over a flat plate in the presence of a magnetic field led to the conclusion that both the skin friction and the heat-transfer rate are reduced by the presence of a magnetic field.

The paper under review is concerned with the free-convection heat transfer of an electrically conductive fluid passing along a vertical plate in laminar flow in the presence of a trans-

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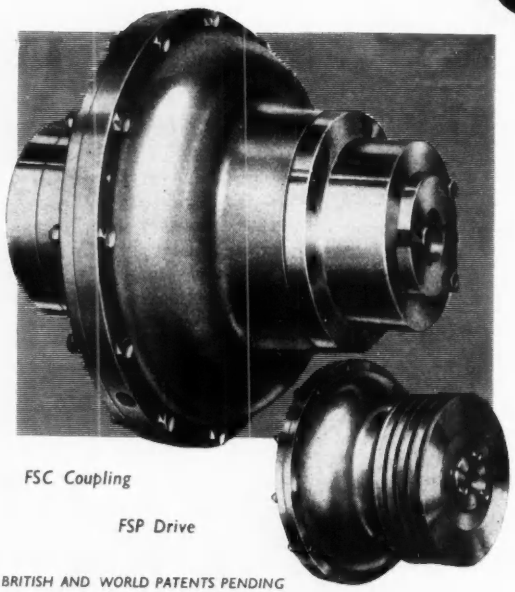

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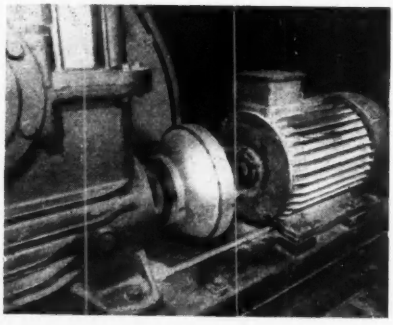

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verse magnetic field. The investigation was conducted with a view to evaluating the effect of the magnetic field on the velocity profile, the temperature profile, and the heat-transfer rate. The boundary-layer equations for self-preserving flows are integrated numerically for unity Prandtl number, and the effect of the transverse magnetic field on the velocity profile, temperature profile, and the rate of heat transfer by convection is discussed. It is concluded that the heat-transfer rate is reduced as the intensity of the magnetic field is increased. Similar equations apply to cases in which the magnetic field intensity varies according to the power $\pm\frac{1}{4}$ of the distance from the leading edge of the plate. It was established that the non-dimensional quantity given by the product of the magnetic parameter and the distance expresses the effectiveness of the magnetic field. It was also found that the velocity profile is flattened and the heat-transfer rate reduced by the magnetic field.

From *Transactions of the Japan Society for Aeronautical and Space Sciences*, Vol. 21, No. 2, 1959, pp. 22–26.

● *AN INNOVATION IN HIGH-RATIO GEARING*

A most unconventional type of gear drive has been developed which can step up or step down speed ratios by as much as 1,000,000 to 1. It can transmit rotary-to-rotary, as well as rotary-to-linear, or linear-to-linear motion. The rotary-to-rotary version has a ring gear with internal teeth mating with a flexible gear with external teeth. These teeth are straight-sided, and both gears have the same circular pitch; hence, the areas of engagement are in full mesh. However, the flexible inner gear has fewer teeth than the outside gear, and its pitch circle is therefore smaller. The third member of the drive is a link with two rollers and rotates within the flexible gear, causing it to mesh with the ring gear progressively at diametrically opposite points. This propagates a travelling strain, or deflection wave, in the flexible gear. If motion of the centre link or " wave generator " is clockwise, and the ring gear is held fixed, the flexible gear will rotate counterclockwise at a slower rate with constant angular velocity. The teeth are stationary where in mesh, thus acting as splines in full contact. The movement of the flexible driven member is confined to the area in which the teeth are disengaged. Each rotation of the centre link moves the flexible gear by a distance equal to the tooth differential between the two gears. Thus, the speed ratio between centre link (input) and flexible gear with, say, 180 teeth in the ring gear and 178 teeth in the flexible gear, is 1 : 89, the input and output rotations being in opposite directions.

It is claimed that the new drive avoids many characteristic difficulties of conventional gear systems. Thus, for instance, it offers a much higher torque capacity than conventional gearing, owing to the fact that in the new drive usually 55% of the teeth are in contact, as compared with 2 to 6% in conventional gears. Mechanical efficiency is high and does not decrease as markedly as in the case of conventional gearing when the speed ratio is increased. By making the inner member capable of adjusting the deflection, backlash can be eliminated.

From *Product Engineering*, U.S.A., February 8, 1960, pp. 47–51.

● *SUPERCAVITATING FLOW PAST SLENDER DELTA WINGS*

The behaviour of two-dimensional, thin, lifting foils with full cavitation in steady unbounded flow is now fairly well understood. However, there do not seem to exist any theoretical results pertaining particularly to the behaviour of three-dimensional lifting wings with full cavitation. When the wing-cavity length is somewhat shorter than the span of the wing, no difficulties would seem to present themselves in the direct extension of lifting line results, but, when the cavity is longer than the span, even the forces on the high aspect-ratio foil may very well be affected not only by the decreased effective angle of attack due to the trailing vortex system, but also by the difference between the two-dimensional and actual cavity shapes. In the extreme case of very low aspect-ratio or slender supercavitating wings, the flow pattern becomes primarily dependent on the " tip " effects, and considerations apply different from those pertaining to moderate aspect-ratio wings. In the case of flat, slender deltas, the possibility exists that the supercavitating flow is essentially conical.

In this paper the theory is developed for a conical flow involving cavities which spring from the leading edges of the delta and cover a part of the top of the wing; the centre part of the wing top is assumed to be wetted by a kind of re-entrant jet flow. Results are obtained for the two separate asymptotic cases in which the cavitation number is either very small or very large. The lift of a fully cavitated wing is estimated to be approximately four-tenth of its fully wetted lift.

From *Journal of Ship Research*, U.S.A., December, 1959, pp. 17–22.

● *BENDING CERAMIC AND IONIC CRYSTALS*

A number of research studies now in progress are concerned with widening the range of application of ceramic materials and ionic crystals by overcoming certain characteristic properties which were hitherto considered innate. Undoubtedly the most important physical property of a metal is its formability by plastic deformation. In contrast, a serious difficulty in

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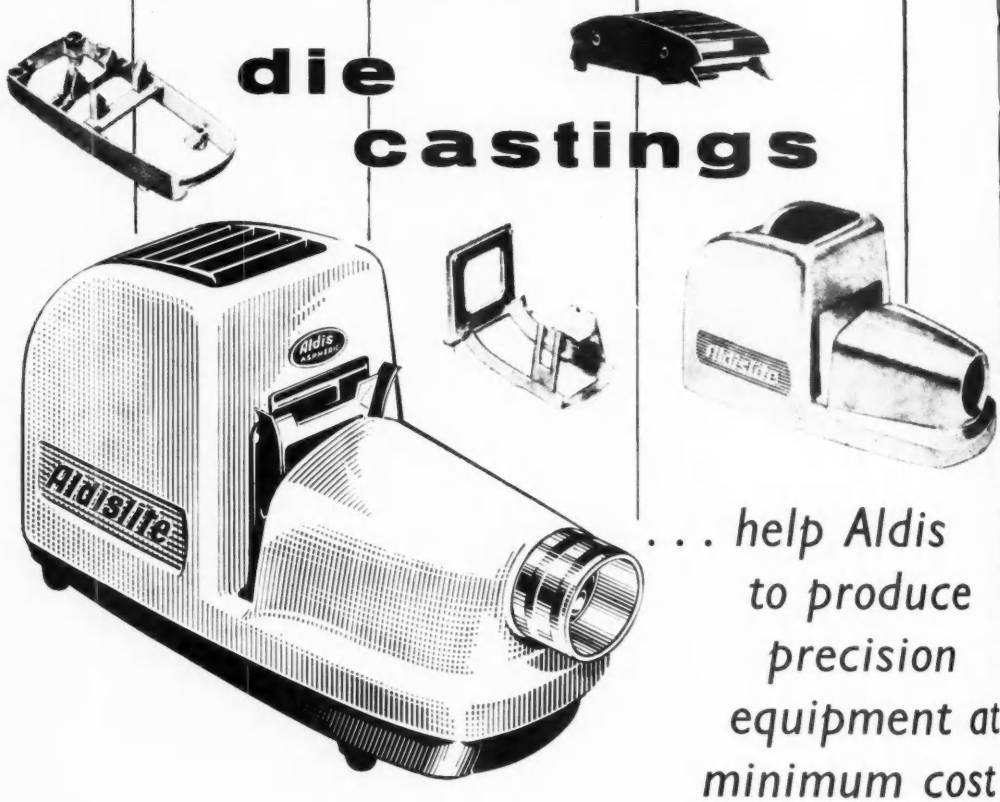

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the utilization of ceramic materials is their inability to be plastically deformed. It has recently been found, however, that a single crystal of magnesia can be bent immediately after cleaving, i.e., after a clean surface is exposed. This observation has led to the conjecture that the embrittled state is not the natural state of the material, but that ductility is lost because of surface contamination.

Using this concept, it has been found possible to bend "clean" crystals of ceramic and ionic materials. However, while the apparent ductility is of considerable interest in the laboratory, it obviously lacks the adaptability required in production processes, so that there is an obvious need for another method of "ductilization" which does not require cleaving or dissolving the material immediately prior to deformation. To this end, a technique has now been developed which will make ionic crystals ductile through the application of a high-voltage direct current across the material during the actual deformation. It has been found possible in this way to bend sodium-chloride crystals into a horseshoe shape and then to bend them in the opposite direction. While this technique has not as yet been extended to magnesia, applications for ionic materials plastically deformed by this method are immediately apparent, including the production of crystal detectors and (perhaps more important) crystal transducers.

From *Electronics*, U.S.A., January 15, 1960, pp. 100, 102, and 105.

● *STUDY OF ICE ADHESION TO SHIPS*

A systematic study of the problem of ice adhesion to ships is now under way at the Material Laboratory of the New York Naval Shipyard, the programme involving applications of surface chemistry and the evaluation of potential ice-phobic formulations and commercial coatings. For this purpose, a special ice-adhesion testing apparatus has been developed for the quantitative investigation of the phenomena involved in ice adhesion. The apparatus is used to measure, under specific conditions, the adhesion of ice in terms of stress in pounds per square inch required to shear the ice horizontally from a surface. In the case of a navy-grey deck paint, ice-adhesion values were found to vary from a minimum of about 75 psi to more than 125 psi. This finding emphasizes the sizeable forces of adhesion which have to be overcome by ice-chippers on the deck of a ship.

Investigations of one ice-phobic coating have shown that ice-adhesion values as low as 2 to 30 psi can be obtained. This coating, which is of the polysiloxane class and combines promising ice-release properties with excellent resistance to water immersion, is said to have withstood more than sixty cycles of water immersion before film failure. The report also states that selected inorganic additives to standard navy-grey paint will give it some ice-phobic quality; in fact, some additives have lowered the initial ice-adhesion values on grey deck paint from 80 psi to the range of 20 to 40 psi. Usually, however, the effect of these additives is only temporary, ice-phobicity soon wearing off. The investigators state that, for a material to be considered as an ice-phobic coating, adhesion values should remain below 5 psi on repeated ice releases for 25 trials with water immersion between ice releases, and for 50 trials with no water immersion between ice releases.

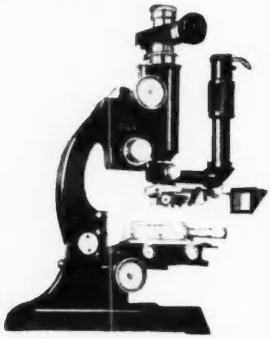
From *Bureau of Ships Journal*, U.S.A., December 1959, pp. 10–11.

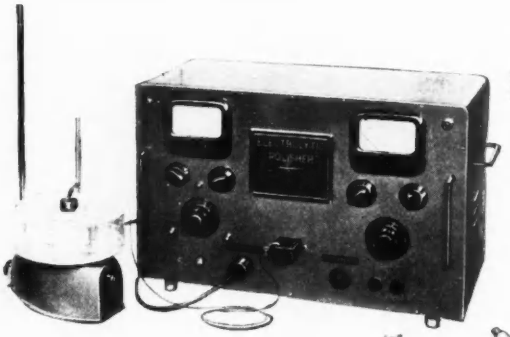
● *FLUIDIZED-BED PROCESS FOR THE PRODUCTION OF HEAVY PLASTIC COATINGS*

Plastic coatings of uniform thickness and high quality are now being produced by the fluidized-bed process. The parts to be coated are first preheated in an oven to a temperature above the melting point of the plastic coating material. The preheat temperature required depends on the type of plastic used, and on the shape, mass, and material of the part. The preheat temperatures required for various plastics range from 250 to 800°F. After preheating, the parts are immersed and moved to and fro in a fluidized bed of the finely divided plastic powders. Fluidization of the powders is produced by an ascending current of gas or air in the tank containing the powders, the powders then behaving in the same way as a fluid. When the individual powder particles contact the heated part, they fuse and adhere to its surface. In many cases the part is post-heated to coalesce the coating completely and to improve its appearance. The thickness of the coating depends on the temperature of the part and on the period of immersion in the fluidized bed. Comparatively heavy finishes, ranging in thickness from about 0·005 to 0·05 in., are produced in a single dip. An important advantage of fluidized-bed coatings is that they are more uniform than conventional solution-type coatings. A fluidized-bed coating closely follows the contours of irregular surfaces; also, it virtually eliminates excessive build-up, sagging and dripping, and has good edge coverage. The fluidized-bed process is well suited for applying solvent-resisting materials, such as nylon and chlorinated polyether, which are difficult to apply by any other method. Thus, in some cases the advantages of a solid plastic can be obtained by using the material as a coating over a less expensive substrate.

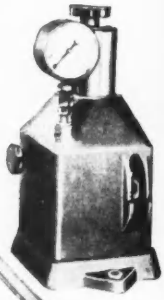
From *Materials in Design Engineering*, U.S.A., February 1960, pp. 91–95.

Micro Hardness Tester





Swirl
Electrolytic Polisher



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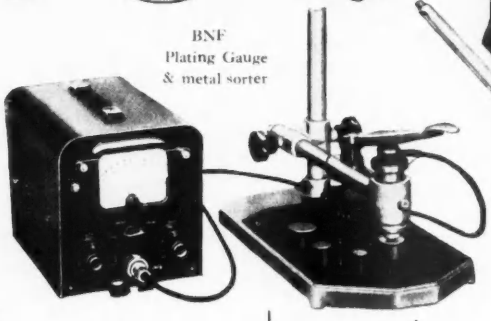

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• *DETERMINATION OF JET FUEL FLOW RATES BY RADIOACTIVE TRACERS*

During the course of investigations using radioactive tracers to measure flow rates of liquids, a circuit was required to measure time intervals of about 25 milliseconds. The particular application involved was the measurement of the rate of flow of fuel to a jet engine. Previous methods used to measure flow rates were considered unsuitable either from the instrumentation point of view, or, in the case of the total-count method, the flow rates encountered were too great. The circuit developed for this purpose uses a Geiger tube as the detecting element. A transistor switch circuit is operated by an initiating pulse, and controls gate circuits for the oscillator and Geiger amplifier circuits. The operating cycle is initiated by a trigger pulse which is amplified by the trigger amplifier and applied to the switch circuit. The switch circuit performs two simultaneous functions, the first of which is to open the gate for the crystal-controlled oscillator, permitting oscillator output to be applied to the recorder, and the second function is to open the gate controlling the detector amplifier, permitting output from the Geiger tube to pass into a scaling circuit of conventional design. Output from the scaling circuit is fed back to the switch circuit, which closes the two gates previously opened. The time elapsed between the initiating trigger and the closing pulse from the scaling circuit is read out from the recording device. Thus, the time interval depends on the pulse rate delivered by the Geiger tube which, in turn, depends on the fuel rate. Performance of this device has proved to be very reliable.

From *Electronics*, U.S.A.,
February 19, 1960, pp. 58–59.

• *DETERMINATION OF PHOSPHORUS AND MANGANESE IN CONVERTER BATHS*

In the blowing operation for the conversion of steel, it is particularly important for the quality of the steel produced and for the economy of the process that the course of the critical metallurgical processes in the molten metal should be established with the greatest possible speed and accuracy during the very short time available during the blow, so that the results obtained can be used for controlling the blowing process. Although numerous attempts have been made to provide continuous information during the blowing operation, especially with reference to the phosphorus content of the bath, no satisfactory solution to the problem has so far been found, because of the presence of numerous overlapping influences in the converter during the very short time available. Research has therefore been limited to working out methods by means of which a characteritics point in the dephosphorization process can be determined and used for predicting the probable end-point of the blow.

A recently patented method of estimating the amount of phosphorus or manganese contained in the bath during the blowing operation is based on the extraction of dust from the converter gases and the determination of the amount of the particular element contained in it. From the amount found in the dust, the amount present in the bath can then be determined from the known proportional relationship between these amounts. This method is based upon the surprising fact that the amount of phosphorus emitted from the converter in the form of fine dust has a definite proportional interrelationship with the phosphorus content of the bath; the same holds true for manganese.

From *Brit. Pat. Spec.* 826, 287,
Hüttenwerk Oberhausen A.G., Oberhausen, Germany.

• *FUSION WELDING OF METAL FOIL*

The need for high-strength, low-weight structures calls for the attainment of joints whose weight is not excessive and whose mechanical properties are equal to those of the metal being fabricated. While the basic nature of welding is compatible with these requirements, inert-gas-shielded tungsten-arc welding is particularly adaptable for the butt-welding of foils. However, careful consideration of a number of the process variables is essential. Only by controlling these variables through good design of all components of the welding equipment can foils of 0·002 to 0·005 in. in thickness be welded. Accurate preparation of the joint edges is essential to achieve successful welds. The volt-ampere characteristic of the low-current arc required for welding of foil necessitates careful selection of the power supply. The arc voltage increases very sharply as the current decreases. The rate of increase is affected by the shielding gas and the arc length. Arc stability is achieved if a well-defined intersection of the volt-ampere curves of the arc and the power supply is developed and if the electrode tip maintains its shape. When a power supply with a sharply drooping volt-ampere characteristic is used in conjunction with a pointed electrode and an argon-helium shielding mixture, rapid arc ignition and satisfactory arc stability are obtained. The contour of the welded joint is influenced by arc- and surface-tension forces acting on the molten weld pool. These forces displace the metal to either side of the seam, so that a thinner section is usually obtained in a plain butt joint. Proper design of the hold-down and backing strips for a given metal thickness limits this effect.

From *Welding Journal*, U.S.A.,
December, 1959, pp. 1182–1191.

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VOL. XXI No. 3 MARCH, 1960

The Effects of Magnetic Fields on the Transfer Characteristics of Metal Particles in Electric Arcs

By P. SHAJENKO

From *Welding Journal*, U.S.A.,
Vol. 39, No. 2, February 1960,
pp. 83s–88s, 9 illustrations

In the arc-welding of heavy ferritic sections, a difficulty often encountered is "arc blow", which refers to a condition in which the welding arc is deflected from the desired target, leading to poor welding. As a result, many methods have been used to counteract arc blow, including changing ground locations, using split grounds, using welding rods of small diameter and with uniform coverings, maintaining smaller welds, making narrow stringer welds, using permanent magnets, demagnetizing the plates to be welded, using specially designed magnetic shunts, using alternating current, etc.

These many apparently unrelated methods used to relieve arc blow indicate lack of a working hypothesis relative to arc-blow-producing phenomena. It is evident that not only the arc, but also the metal transfer is affected by arc blow, but the manner in which arc blow affects metal transfer has not been clearly understood. The problem has been further complicated because of the meagre knowledge available on the subject of metal transfer during welding. The object of this paper is, therefore, to present a hypothesis which explains the observed phenomena associated with arc blow.

During the investigation of magnetic arc blow it was observed that metal transfer from one electrode to another was affected by the presence of a magnetic field. This could not be attributed to the direct interaction between the magnetic field and weld metal; however, it was assumed that the magnetic field in some way affected metal-transfer forces. Subsequent investigations based on this assumption provided information needed for a better understanding of the transfer characteristics of uncharged metal particles in the welding process.

In this investigation, two ferritic metal plates of $\frac{1}{2}$-in. thickness were used. Each plate was wound with 120 turns of No. 12 wire and connected to a d.c. variable-voltage reversible-polarity power supply. Magnetic-field density in the air gap between the welding plates was measured, prior to welding, with a flux-meter.

The following parameters were controlled:—

(a) Magnetic-field density in the air gap.
(b) Direction of the magnetic field.
(c) Welding-rod material, i.e., ferritic and austenitic.
(d) Welding-rod covering.

Welding was performed with covered ferritic electrodes of $\frac{1}{4}$-in. diameter. A constant welding current of 240 A was maintained, while the magnetic-flux density was gradually increased from 0 to 550 gauss.

At zero field density in the air gap, good welds were produced and no arc blow was noticed. As the plates were gradually magnetized, the arc blow first became noticeable at flux densities of about 160 gauss. The welding arc was deflected from the target, and heavier-than-usual spattering of metal was evident. The difficulty experienced at this density was found to be dependent on the direction of arc deflection and was experienced only when the arc was deflected opposite to the direction of welding. As the flux density was further increased to 320 gauss, severe arc blow was encountered. The arc was intermittently extinguished with metal spattering prevalent, and welds of poor quality and appearance were produced.

Investigations were made during welding with flux densities in the air gap above 500 gauss. Under this extremely severe condition, it was found that metal spattering was in the direction of arc blow and that metal particles were projected considerable distances, particles of $\frac{3}{16}$-in. diameter being projected as much as 4 ft. It was also noted that the welding rod was consumed on the side to which the arc was deflected.

Arc blow was experienced with both ferritic and austenitic electrodes, and it is of interest to note that the arc-blow effect was produced when welding with a rod from which the covering had been removed on one side and with no magnetic field in the air gap. In this case, also, the arc became unstable and metal spattering was directed from the bare side of the electrode.

When the magnetic flux was adjusted to 480 gauss in the air gap, heavy arc blow resulted. The arc was dispersed and deflected from the target, and more than $\frac{3}{4}$ in. of the welding rod was consumed on one side, thereby effectively increasing the arc length. No weld deposit could be made at this field density.

Based on these observations, investigations were made into the effectiveness of compensating magnetic fields, and the possibility of preventing unequal consumption of the welding rod by rotation. In this connection, since an electromagnet can be used to produce and to control arc blow, it was considered convenient to study arc behaviour when an arc-blow-producing magnetic field was compensated by an opposing magnetic field. For this purpose, a permanent magnet of 3-lb weight and 310 gauss was used to create the opposing field and was placed across the air gap between two ferritic metal plates previously magnetized to produce 320 gauss in the

air gap. The compensating effect of the permanent magnet on the arc was readily noticeable, although satisfactory conditions for welding were difficult to establish. This was because flux density varies throughout the gap and because the magnetic field produced by a permanent magnet is localized by magnet location, so that the progressing arc is subjected to a varying magnetic field.

A detailed study of field interaction and the resulting effect on the welding arc was made, using special test equipment in which the arc can be thought of, electrically, as a flexible extension of the welding rod and was therefore simulated by a conducting rod extending into a mercury pool. The mercury pool was used to provide the electrical connection at one end of the rod and to permit rod movement under magnetic deflecting forces. Strain gauges were mounted on the welding rod to sense components of deflecting force on the rod, from which the amplitude and directions of the force could be determined. Signals from associated bridge circuits were indicated on zero-centred micro-ammeters. The polarity and magnitude of magnetism in the air gap were controlled with magnetizing coils.

Measurements were made of the deflecting force on the rod while carrying 120 A, as the flux density in the air gap was varied in steps of 100 gauss, ranging from 0 to 500 gauss. These values are average, since the field density varied across the 10-in. wide plate. Variations were as high as 68 gauss.

The deflecting force acting on the rod is proportional to the current flowing in the rod, the field density in the air gap, and the rod length effectively below the mercury surface. The direction of the deflecting force is perpendicular to the plane of current flow and magnetic field in the air gap.

Assuming the rod to be perpendicular to the two rectangular welding plates and the rod current to be perpendicular to the magnetizing field, the direction of the deflecting force should be along the air gap. However, measurements revealed deviations from this direction of as much as 18 deg. with 100 gauss in the air gap. At 500 gauss, the deviation was negligible, because, at low flux density, the magnetic field due to rod current significantly contributes to the total magnetic field but, at high flux density, the magnetizing field is predominant. Ground location is of considerable importance at magnetic field densities below 160 gauss. With a specific ground location, it was possible to balance the rod-deflecting force completely.

In an attempt to balance magnetizing fields at the five field densities with a permanent magnet, it was found that, in each case, only at one particular location of the permanent magnet was it possible to produce balance. Also, it is necessary that the field of the permanent magnet be opposite in polarity to the magnetizing field.

In order to overcome these difficulties, a d.c. electromagnet of patented design was made which provided a controllable magnetic-field strength of reversible polarity, utilizing a Wheatstone-bridge type of control unit. Fixed resistors in the control circuit were of 25-A capacity and 0·45 ohm each. The electromagnet consisted of 320 turns of No. 12 wire wound on a ferritic core. With a variable resistor (15 ohms, 25 A) adjusted to the balance position, no current flows through the electromagnet coil. The polarity of the electromagnet can be changed by adjusting this resistor to either side of the balance position. Increasing the bridge unbalance increases the magnetic-field strength. Because the electromagnet produces a field of easily controlled magnitude and polarity, any field variations about the rod can be balanced. Utilized in actual welding operations, this electromagnet effectively balanced magnetizing fields up to 550 gauss. At the balanced position, the arc was stable, the rod was consumed evenly, and there was normal metal transfer, producing good welds.

In order to study the effect of uneven consumption of the welding rod, a welding gun of patented design was constructed to rotate the rod during welding. The welding plates were gradually magnetized from 0 to 480 gauss in the air gap, and welding was started with a non-rotating electrode. As the magnetic field was increased to approximately 200 gauss, arc blow was encountered and directed spattering of metal noticed. When the welding rod was rotated, welding was improved. A further increase in flux density required shortening of the arc. Rod rotation permitted shortening the arc to a minimum, without the rod sticking to the plates. A gas layer maintained between the welding rod and the welding plate offers electrical resistance which compensates for shortening the arc.

Uneven consumption of the welding rod and all consequent effects were eliminated by rod rotation. It should be noted that good results using a rotating electrode were not immediately attained. During normal welding, with no arc-deflection forces present, the operator can maintain a relatively long arc; however, when arc-deflection forces are present, as in cases where rotating electrodes would be used, it is important that a short arc be maintained. This requires the operator to hold a short arc at all times, as an increase in arc length will result in arc blow. Extremely heavy arc blow requires that welding be in the direction of arc blow.

Theoretical Considerations

Several theories have been proposed regarding metal transfer in electric arcs, and these can be grouped around two basic concepts, i.e., globular metal transfer and metal transfer in the form of minute particles. Thus, Escholz* has advanced a theory that metal is transferred mainly in liquid form. Under welding heat, the top of the welding rod melts, forming globules which, owing to continuous growing, make contact with the pool on the plate, whereupon the forces of adhesion and surface tension of the plate overcome the combined forces of cohesion and surface tension acting to hold the globule to the electrode surface.

On the other hand, Larson† believes that metal transfer takes place in the form of small particles of about 0·001-in. diameter, with occasional particles over 0·010 in. passing across the arc at speeds up to 120 mph. It takes 0·002 sec for a large particle, and 0·001 sec for small particles to cover the distance between electrodes, so that particles are transferred without short-circuiting of the arc. Globular transfer of metal necessarily requires short-circuiting of the arc each time the globule transfers.

Arc study, however, cannot fully account for both concepts. During welding, the arc is short-circuited, but at a much lower rate than would be necessary for globular transfer. Although Larson omits further explanation, his data are in close agreement with the data obtained in this investigation. From this study, it is possible to picture more clearly the metal-transfer mechanism.

Welding heat is generated in proportion to the voltage drops along the welding arc. On the electrode surfaces,

* O. H. Escholz: *The Welding Encylopedia*, 12th edition, 1947, pp. 745-746

† L. J. Larson: *Ibid.*, pp. 744-746.

it localizes at cathode and anode spots which cover comparatively small areas, and the temperature of the material at these spots may therefore rise above boiling point. The spots are in continuous movement on the electrode surface under the influence of electromagnetic, thermodynamic, and mechanical forces, the speed of this movement influencing the spot temperature. The temperature is much higher at the welding rod than on the metal plate, because the spot on the welding rod has less area about which to move and the welding rod has less mass to dissipate heat. In turn, the higher temperature makes the arc more attracted to a particular spot on the electrode surface, causing deeper local penetration. Metal in the immediate vicinity of the spot is in a molten state. The tremendous release of welding heat over a small area on the welding rod causes explosions which project the molten metal away from the tip of the welding rod.

The magnitudes of these explosions are random, resulting in random distribution in the speeds and sizes of metal particles, some of which will be of sufficient size to short-circuit the arc. Higher temperatures produce stronger explosions, resulting in smaller and more energetic metal particles, which are directed from the surface of the rod tip to the molten pool on the metal plate. Heavy bombardment of the metal pool by these particles produces craters, the depth of which is a good measure of penetration and the quality of the weld. Also, a considerable amount of metal transfer is due to sub-surface explosions within the tip of the welding rod. Under intense welding heat, the gas available in the tip of the rod due to evolution, vaporization, decomposition, etc., causes explosions which accelerate metal particles.

At lower temperatures, the magnitude and number of explosions decrease, and other metal-transfer forces, such as gravity and capillary attraction, become predominant. This type of metal transfer is experienced when welding with a bare electrode.

The welding-rod covering, in addition to preventing oxidation, concentrates heat energy at the tip of the welding rod by providing insulation, thereby maintaining the tip at a much higher temperature and producing better metal transfer. The melting rate of the covering is lower than that of the filler metal, maintaining a concave shape in the welding-rod tip, with a focusing effect on metal particles. Only high-energy, randomly directed particles are able to escape the molten pool under these conditions, resulting in normal spattering.

This point of view readily describes overhead welding, where gravity and capillary attraction without direct contact between electrodes is not possible. In overhead welding, higher currents and a shorter arc length are desirable, since they both contribute to the magnitude of explosions. Forces of lower magnitude will be sufficient to lift metal particles across shorter arcs, increasing welding speed.

Re-examining the methods used to counteract arc blow, it may be said, in the light of the above findings, that:—

(a) The use of a welding rod of smaller diameter may relieve arc blow, because the arc length can be kept shorter with less consumption on the side of the rod, providing better heat concentration.

(b) The use of a welding rod with uniform covering may relieve arc blow, because the arc may break through the lighter covering, thus destroying the particle-guiding and heat-concentrating properties of the rod covering.

(c) The use of consumable-electrode welding prevents arc blow, because the arc length is automatically kept short and the small electrode and higher current density used provide the higher temperature required for good welding.

(d) Maintaining a smaller pool may relieve arc blow, because heat is concentrated in a smaller area. The same can be said about making narrow stringer-weld melts.

The degree of effectiveness using these methods depends on the magnitude of arc-blow-producing forces. If they reach a certain level, these methods are useless.

Other methods used to relieve arc blow in practical applications are aimed at preventing or balancing arc-deflecting forces. Mechanical and thermodynamic forces are sometimes very troublesome and, in general, can be eliminated easily. They are, in most cases, due to high wind velocity in the vicinity of the arc or to improper temperatures of welding materials. It was found that the arc could be completely extinguished by air currents of approximately 1000 fpm and that preheating of welding materials before welding, or eliminating air currents in the vicinity of the arc, in many cases relieves arc blow. Electromagnetic forces which produce arc blow, however, are more complex in their origin and in the way they affect the arc.

The magnetic forces affecting the arc can be due to welding current, residual magnetism in welding plates, and any externally imposed magnetic field. A magnetic field due to welding current exerts forces only when asymmetry of this magnetic field exists. Frequent causes of such asymmetry are ground location, mass distribution around the arc, and heterogeneity in the electrical properties of welded material.

Arc deflection due to welding current can be experienced with non-ferritic, as well as ferritic, materials; however, the reluctance of the materials may determine deflection characteristics. The lines of magnetic flux around the welding arc follow the path of least reluctance. Where a difference in reluctance exists, asymmetry of the magnetic field will result. An asymmetrical magnetic field around the welding arc causes arc deflection in both a.c. and d.c. welding; however, the changing magnetic field due to a.c. welding induces eddy currents in the welding plates, producing in turn fields neutralizing those due to welding current.

This investigation has revealed that arc blow is of minor magnitude when only magnetic fields due to welding current are present. It can be opposed comparatively easily by various techniques, such as using balanced ground end strips, changing ground locations, or changing the mass of magnetic materials.

Arc blow severe enough to extinguish the arc is essentially due to interaction between the residual magnetism in the welding plates and magnetism due to welding arc current. Residual magnetism may be present in the plates in the as-received condition or may be introduced during subsequent operations, such as lifting with electromagnets. Even though the magnetic-field density in each of the two plates may be low when separated by large distances, the density greatly increases as the plates are brought into position for the welding operation. From this, it can be concluded that the only effective way of combating arc blow is to balance deflection forces or counteract their effect on the arc during welding. These principles are incorporated in the controllable electromagnet and the rotary welding rod described above; both have been used successfully under extreme laboratory conditions as well as in practice.

Welding as a Means of Improving Notch Fatigue Strength

By H. WOLF

From *Schweissen und Schneiden*, Germany,
Vol 12, No. 1, 1960,
pp. 10–14, 11 illustrations

IT has been shown that, if certain highly stressed structural steel components in an assembly are replaced by copper components, the load may be redistributed more uniformly and the danger of fatigue reduced[1]. Also, components welded with austenitic electrodes have sometimes shown a higher notch fatigue strength than similar components welded with carbon-steel electrodes or even unwelded components[2]. This effect may be due to the low notch sensitivity of austenitic steels[3] or to the low value of Young's modulus E of the austenitic weld material causing a reduction in the stresses in the dangerous region. Fatigue tests on notched steel specimens with fillet welds having low values of E surrounding the notch have confirmed the effect[4].

If S_m is the mean stress in the total minimum cross-sectional area F of a notched bar, and a part F_f of the area F is occupied by a filler material of Young's modulus E_f, welded or otherwise rigidly joined to the parent material of modulus E_g, then the mean stresses S_{mg} in the parent material and S_{mf} in the filler material can be calculated[4] by the simple formulae

$$S_{mg} = \frac{S_m}{\frac{F_f}{F}\left(\frac{E_f}{E_g} - 1\right) + 1} \quad .. \quad .. \quad (1)$$

$$\text{and } S_{mf} = \frac{S_m}{\frac{F_f}{F}\left(1 - \frac{E_g}{E_f}\right) + \frac{E_g}{E_f}} \quad .. \quad .. \quad (2)$$

It will be seen that these stresses depend on the ratio of Young's modulus and the relative areas occupied by the two materials in the narrowest cross-section.

Fig. 1 shows actual stress distributions S in a notched tensile testpiece with a stress-concentration factor α_k, according to Neuber[5] of 3·4, while Fig. 2 shows the stress distributions in a differently notched tensile testpiece with a stress-concentration factor α_k of 2·0, in both cases without filler weld material and with filler weld material around the notch up to the dotted circles. In both Figs. 1 and 2, the ratio E_g/E_f is 1·86, and the stress curves are plotted from strain measurements taken entirely in the elastic range of the specimen with a mechanical-optical extensometer of 3-mm gauge length, and extrapolated to the boundary. The welds considerably reduce the stress level in the filler material and increase the stress level in the parent core. An increase in the area of the filler material increases the stress level in the remaining parent material. At the transition, there is a jump in stresses for equal strains of parent and filler material. The microstructure showed practically no zone of mixed material[4]. The mean stresses in eqs. (1) and (2) are also shown dotted and indicate the relative loading of the two materials. The measured stress curves confirm that a filler weld with a low value of E reduces the notch root

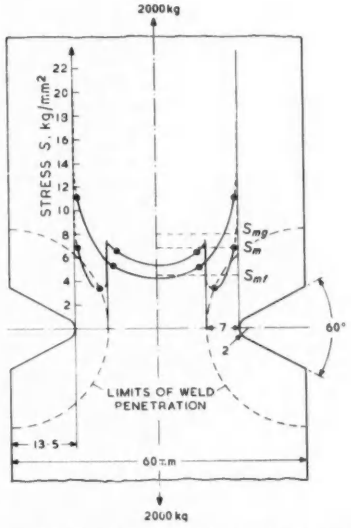


Fig. 1. Stress distribution in a tensile testpiece under a load of 2000 kg and having a stress-concentration factor of 3·4, with and without a filler weld.

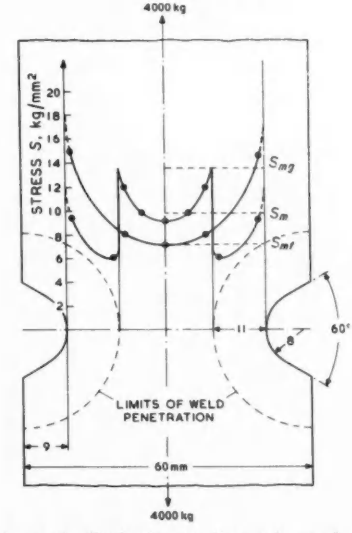


Fig. 2. Stress distribution in a tensile testpiece under a load of 4000 kg and having a stress-concentration factor of 2·0, with and without a filler weld.

stress. The stress reduction, however, is less than that which would correspond to the ratio of the E-values.

Rotating-bending tests at 3000 rpm were carried out on a Schenck machine giving a constant bending moment. The three types of specimen tested are shown in Fig. 3, the dotted circles in types (1) and (2) indicating

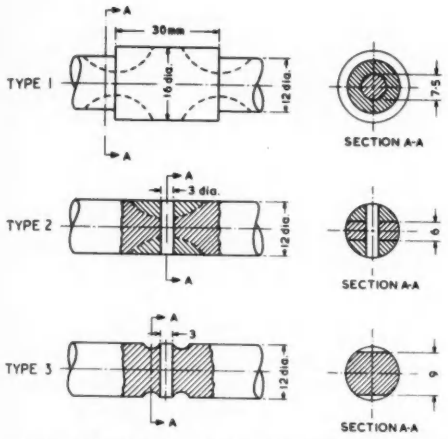


Fig. 3. Types of testpieces used in rotating-bending fatigue tests.

the extent of weld penetration, while the specimen of type (3) was used to indicate the effect of relieving grooves and was not welded. The parent metal was a drawn steel bar of 62-kg/mm² U.T.S., with a bending fatigue strength of 36 kg/mm², and the welding rods consisted of an austenitic Cr-Ni-Mn alloy with an *E*-value of 16,700 kg/mm², and of two types of Cu-Al-Fe bronze with *E*-values of 11,300 kg/mm², differing slightly in strength and elongation. Welding presented no difficulties, though pores could not always be avoided.

A number of testpieces of each of these three types were made and tested, the mean values of the test results being plotted in Figs. 4 and 5. Fig. 4 shows the *S-N* curves for specimens of type (1), while Fig. 5 shows the *S-N* curves for specimens of type (2) and (3). In all cases, the stresses refer to the smallest cross-section, but do not take into account the transverse hole in the case of specimens of type (2). These curves clearly show the improvement obtained by welding and the lesser improvement resulting from the use of relieving grooves, the percentage improvement corresponding to 2×10^6 load cycles being summarized in Table I. The introduction of compressive stresses near the ends of the transverse hole has been shown[6] to improve fatigue strength by as much as 36%. Welding is therefore equally effective and is in many cases simpler to apply. A further improvement can perhaps be obtained by surface-rolling of the weld material, and tests in this connection are planned.

The fatigue cracks in the specimens of type (1) did not start in the fillet, as was the case with unwelded specimens, but between 3 and 5 mm from the fillet in the filler material, which has the lower fatigue strength. Even large pores directly underneath the fillet did not deflect the start or propagation of the crack (Fig. 6). In specimens of type (2), a crack usually started at the end of the transverse hole but did not propagate far, the crack leading to fracture starting near the end of the welded area and propagating into the hole (Fig. 7). In specimens of type (3), the crack started in one of the relieving grooves and propagated towards the hole.

With sound welding, the improvement obtained thus depends on the ratio of the *E*-values, the relative area of the weld material, and its fatigue strength. With austenitic electrodes, the fatigue strength rises roughly in accordance with the ratio E_a/E_f; with Cu-Al-Fe electrodes the improvement is less, because of the lower fatigue strength of the weld material. Nevertheless, in rotating

TABLE I: ENDURANCE VALUES AT 2×10^6 LOAD CYCLES

Treatment	Specimen			
	Type (1)		Types (2) and (3)	
	Stress [kg/mm²]	Improvement [%]	Stress [kg/mm²]	Improvement [%]
Unwelded	17·5	—	18·7	—
Welded with Cr-Ni-Mn alloy	21·2	21·2	22·6	20·8
Cu-Fe-Al bronze (type 1)	21·2	21·2	23·2	24·1
Cu-Fe-Al bronze (type 2)	22·6	29·1	25·3	35·3
Relieving grooves	—	—	20·6	10·2

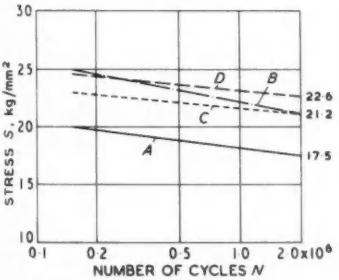
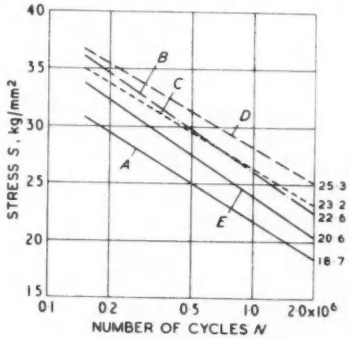


Fig. 4. (left) ***S-N* curves for testpieces of type (1).**
(A) Unwelded.
(B) Welded with Cr-Ni-Mn alloy.
(C) Welded with Cu-Fe-Al bronze (type 1).
(D) Welded with Cu-Fe-Al bronze (type 2).

Fig. 5. (right) ***S-N* curves for testpieces of types (2) and (3).**
(A) Unwelded.
(B) Welded with Cr-Ni-Mn alloy.
(C) Welded with Cu-Fe-Al bronze (type 1).
(D) Welded with Cu-Fe-Al bronze (type 2).
(E) Relieving grooves.



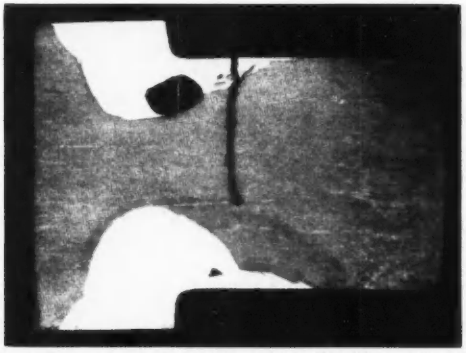


Fig. 6. Fatigue crack in a testpiece of type (1) with an austenitic filler weld containing a large fault.

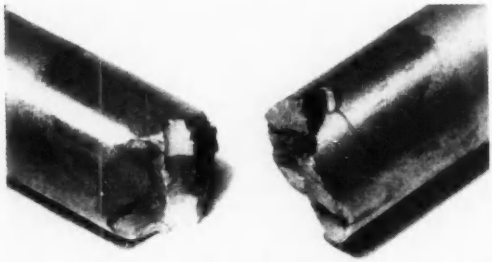


Fig. 7. Fatigue fracture of a testpiece of type (2) with a filler weld of Cu-Fe-Al bronze.

bending, the Cu-Al-Fe welds still show superior fatigue values, whereas in push-pull tests on steel strips austenitic welds are superior[4]. With the small testpieces used, it is difficult to obtain absolutely sound and homogeneous welds, and greater improvements can be expected on larger structural components with notches. In principle, the improvement in the notch fatigue strength obtained by welding with a material having a low E-value has been proved, but further extensive tests are required for the practical application of this method. These tests will include different forms of notches, different stress systems (e.g., torsion), and different and perhaps more advantageous welding materials specially produced for the purpose.

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The Design of Bearings for Large Turbines

By P. C. WARNER

From *Mechanical Engineering*, U.S.A., Vol. 82, No. 2, February 1960, pp. 82–85, 9 illustrations

THE economic considerations involved require bearings for electric-utility turbines and for the larger-sized industrial units to be very conservative in design, and they normally lead relatively inconspicuous and trouble-free lives. Recent developments have permitted marked improvement in machine design through control of the occasional troubles arising, and these are to some degree common to a large class of bearings.

The usual functions of journal bearings are almost invariably well-served. Because of the use of appropriate bearing-load limitations, turning-gear operation (extremely low speed) has been no problem in recent years, even though turning-gear speeds have been reduced in some cases. The policy of purposely maintaining bearing loads at very conservative levels at all times for reasons of reliability is felt to be basically sound, although there are some obvious drawbacks.

Angular alignment of the bearing to the journal is one of the most important aspects of bearing operation and exerts such a strong influence that bearings may be typed according to this feature. One of the most widely used types of journal bearings is the spherically keyed bearing, in which angular alignment is achieved by the sliding of the spherical keys in the spherical seat. Although most of the bearings on a modern unit are of this general type, this bearing does not readily align itself to the shaft once it is carrying load, because of the relatively large friction forces at the keys. Consequently, this type of bearing is not usually employed on the hot end of large machines, where temperature-caused distortions would require frequent angular shifting of the bearing to maintain adequate alignment. As a result of a number of cases of cracked babbitt (a fatigue problem) some 15 years ago, resulting principally from these reasons, the flex-plate design of bearing support was developed, in which the support is so designed that any angular misalignment of the journal and bearing will cause a bending and/or twisting moment on the flexible support plates, deflecting the plates in such a way as to reduce the angular misalignment. This design has been quite successful, and very few cases of cracked babbitt have occurred on bearings supported in this manner. In most cases where cracking has occurred, abnormally large rotor vibrations had been endured for some time.

One other alignment scheme appears attractive, although it is not currently in widespread use on electric-utility turbines. The bearing is of a multiple-pad type, each pad being supported on a spherical button, thereby enabling it to align itself completely to the journal. This type of bearing has been used on large water-wheel generators with excellent results. The fact that the bearing is of the tilting-pad type implies other properties, aside from successful support of the rotor, which can be extremely important.

Quite apart from the primary properties of a journal bearing which enable it to support the rotor successfully, other properties are sometimes also exhibited. Certain of these properties are harmful, others beneficial. It has been known for some time, for example, that conventional oil-film journal bearings exert a very strong beneficial influence on the unbalance vibration of rotors, particularly at critical speeds. Only recently, however, have these properties been determined by experiment and put to practical use in rotor design, and their application has permitted a major increase in the accuracy of critical-speed calculations. In fact, certain by no means infrequent cases may be cited where actual critical speeds are 50% or less of the critical speed calculated on the basis of conventional rigid-support assumptions. In all these cases, inclusion of bearing-oil-film properties in the calculation permits accurate prediction of the critical speeds.

While the effect of the bearing oil films on the value of the critical speed is important, undoubtedly the most important aspect of bearing properties is the limitation of vibration at the critical speed to relatively low values, thereby permitting operation of machines, with commercial balance or worse, above, below, or on critical speeds. By way of comparison, a turbine blade with good damping will have a vibration magnification at resonance of roughly 100 times, whereas a rotor with normal bearing damping will exhibit a magnification at resonance of roughly 5 or less. It can therefore be seen that only oil-film damping makes possible the flexible rotor designs used in most modern equipment.

In direct contrast to these beneficial properties of journal bearings are the properties which lead to the self-excited vibration known as oil-whip. While oil-whip has been a problem for years with high-speed machinery employing lightly loaded conventional journal bearings, only recently have events indicated a need for greater care in this regard in the design of power-station turbines. This need has been brought about by the trend towards relatively lightweight high-pressure rotors with their big journals for reasons of torque, and by the large partial-admission reactions which lead to wide variations in bearing load as operating conditions change.

Oil-whip is a vibration characterized by relative motion between journal and bearing, the journal centre moving in an area-enclosing path in the direction of journal rotation. Usually, though not always, the rotor is the major vibrating element. The frequency of vibration is invariably less than half journal-rotational frequency, and this is the basis of recognition of oil-whip in practical cases. It is this frequency property which distinguishes oil-whip from sub-harmonic resonance, which is another, more common, low-frequency vibration for which the corrective measures are in most cases approximately the opposite of those used with oil-whip.

When oil-whip is encountered, the usual corrective measures are to restore bearing clearance or oil viscosity to normal if either is out of line, to use a narrower bearing, or to groove the bearings, sometimes axially, but usually circumferentially. In severe cases, where these cures are marginal or inadequate, it is deemed advisable to employ the tilting-pad type of journal bearing. Whereas bearings whose oil-film boundaries are fixed will support oil-whip at some speed, despite grooving or other special contouring, the tilting-pad type of journal bearing will not support oil-whip, irrespective of the speed of rotation or the system to which it is applied. These bearings may thus be correctly categorized as a completely stable type and have been used for some years in difficult high-speed applications. They have an excellent record, their chief disadvantage being a markedly higher cost.

One usual design of tilting-pad bearing has the pads rocking on pins. If, instead of a pin, a button is used, then the anti-oil whip properties are combined with an excellent alignment feature.

The level of reliability of the journal bearing has not been quite equalled by the thrust bearing. Furthermore, the consequences of a thrust failure tend to be more serious than those of a journal-bearing failure, and this has led to a development programme to improve the reliability and capacity of thrust bearings, and to the use of instruments and devices to monitor and protect the thrust bearing and turbine from damage. It is felt that the low level of thrust failure in recent years is due, at least in part, to these efforts.

To protect the thrust bearing, as well as turbine, thermocouples in contact with the babbitt in the thrust shoes, and on occasion a thrust-measuring-and-recording device, are used. Recently, the trend has been to regard the thrust recorder as essentially an instrument which is used to verify the thrust levels in new designs.

A reasonably high degree of success has been achieved with thermocouples in the thrust-bearing shoes. In a number of instances, dangerous situations have been indicated in time to permit correction before failure. The location of these thermocouples is in certain cases such that an estimate of the adequacy of oil flow may be made, as well as a very rough estimate of the load the bearing is carrying. A limiting babbitt temperature of 180°F at the centre of the shoe still appears to be reasonable for normal operation.

To protect against the possibility that occasionally trouble may not be indicated soon enough to anticipate complete failure of the bearing and allow the machine to be shut down to prevent serious damage, a hydraulic thrust trip is now being applied to all electric-utility turbines. The device consists essentially of two nozzles at a specified distance from either side of a disc on the turbine shaft at, or near, the thrust bearing. These nozzles are supplied with oil through orifices from the high-pressure oil system and have a pressure take-off on each side through a check valve to an alarm and a trip device, the alarm device being electrical, and the trip device either electrical or hydraulic. These components are so designed that, as the disc approaches one of the nozzles because of wear or wiping of the thrust shoes, the nozzle-to-disc distance tends to become the limiting restriction in the oil line and takes an increasing portion of the available pressure drop, thereby increasing the pressure in the alarm-trip line. When this pressure reaches the alarm or trip setting, the appropriate action occurs. The thrust bearing will not be saved, but the generous margin between the trip setting and serious internal contact will trip the machine in time to eliminate any major damage to the machine. The device is also designed to be readily tested during turbine operation.

Bearing Research

In addition to the development of these protective devices, research and development have been carried out on thrust bearings themselves. In fact, much of the information and data on the thermocouples used in thrust shoes is a direct product of these tests. Commercial designs of the 72-sq in. bearing size can be tested in the equipment over a speed range of 1800 to 6000 rpm, a load range of 0 to 2000 psi, and oil flow ranging from 0 to 75 gpm per bearing. The bearings are suitably instrumented with thermocouples and oil-film thickness gauges, and are tested two at a time by loading against each other.

The thermocouples on the leading edge of the bearing give an excellent indication of the adequacy of oil flow, while the rise in temperature across the shoe gives a rough indication of the load on the shoe. Some typical results and one of the useful lessons learned to date are shown in Fig. 1, which illustrates the extreme importance of sufficient oil flow for most conditions of operation. It will be seen that, with low oil flow at 6000 rpm, the oil is heated 70°F before it ever reaches the thrust shoe. This, of course, is due to the entry of hot oil from the discharge of the previous shoe without sufficient dilution by cold supply oil. A number of cases of field

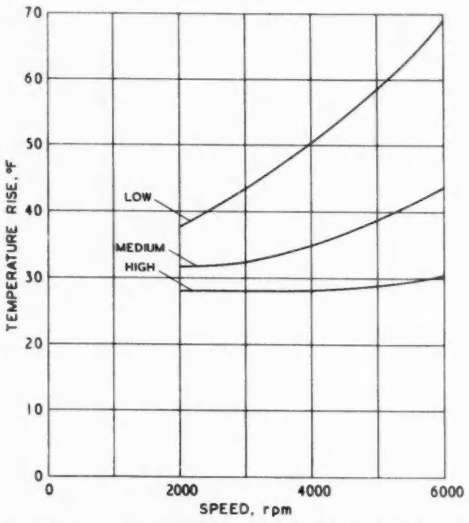

Fig. 1. Temperature rise between cooler outlet and leading edge of the shoe as a function of speed, with a load of 400 psi and under conditions of high, medium, and low oil flow.

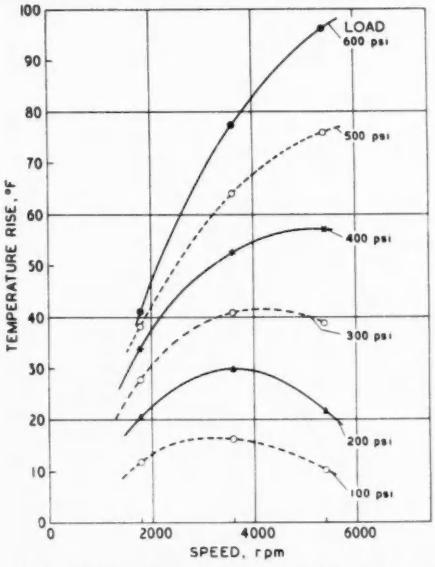

Fig. 2. Temperature rise across the shoe (leading edge to centre) as a function of speed under different conditions of load.

trouble have been cleared up through the recognition of this simple basic principle. The results obtained so far are illustrated in Fig. 2, giving the variation of the temperature rise across the shoe with speed and load.

In order to obtain some data on the maximum allowable size of dirt particles in lubricating systems and an idea of the order of magnitude of collar and shoe distortions of practical importance, oil-film thicknesses have been measured by an electrical method. Some typical results for the minimum oil-film thickness on the trailing edge of two different shoes are given in Fig. 3. While the two shoes are at somewhat different levels, the trends

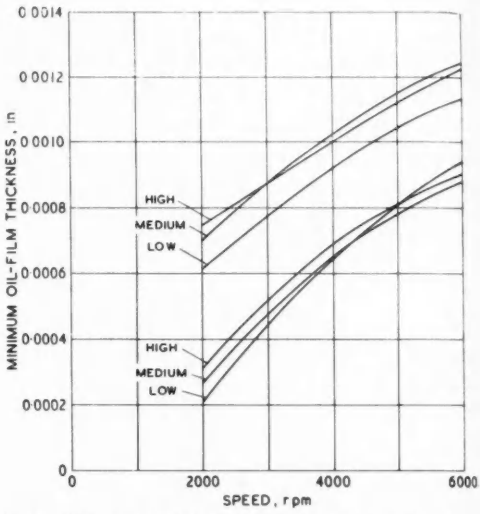

Fig. 3. Minimum oil-film thickness on the trailing edge of two different shoes as a function of speed, with a load of 400 psi and under conditions of high, medium, and low oil flow.

are quite similar. From these data it is clear that normal film thicknesses are considerably less than 0·001 in., so that distortions or geometrical inaccuracies of roughly 0·00025 in. or less are quite important in their effect on shoe load-carrying capacity. This is further evidenced by the fairly common field experience of finding the first signs of distress at, or near, the centre of the shoe. This result has also occurred in tests when the load and speed were too great for the oil flow.

While the characteristics of bearings under normal operating conditions are of great interest to the designer, operation under extreme conditions is also of prime interest. In a series of ultimate-load tests, preselected speeds and oil flows are maintained while load is increased until the bearing fails. These tests differ from field operation in the essentially steady application of load, the shorter period of time, and in the employment of a 10-micron filter in the test device.

Failure loads which are in the neighbourhood of 1000 psi and higher vary with speed and oil flow. More attention to detailed bearing design should increase these attainable failure loads appreciably.

Variables other than those normally associated with bearing operation occasionally enter into the determination of bearing life and/or reliability. One well-known example is cleanliness of the lubricating system, while another is electrical pitting of bearings, as recently experienced in an industrial machine. The individual pits are small compared with the usual scratches, and there would seem to be room for some doubt as to the deleterious effects of such pitting, particularly with a bearing whose shoes are free to tilt and to assume a new inclination, should wear occur in one particular area. It can hardly be argued, however, that such pitting is beneficial; consequently, a grounding brush is supplied with each new machine which does not have water glands.

In conclusion, it may be said that careful bearing design will not only improve bearing reliability, but can markedly improve machine performance with respect to rotor vibrations.

New Metallographic Etching Techniques for Steel and Uranium

In this article, which is a composite of two separate articles, it is shown (Vilella and Kindle) that, apart from its known advantages, sodium bisulphite has the ability to etch untempered martensite as fast as it etches practically all other microconstituents of steel. Details are also given (Posey) of a new chemical etchant which permits micro-examination of uranium under bright-field illumination.

By J. R. VILELLA and W. F. KINDLE
and
W. N. POSEY

From *Metal Progress*, U.S.A.,
Vol. 76, No. 6, December 1959,
pp. 99–102, 8 illustrations

THE use of aqueous solutions of sodium bisulphite ($NaHSO_3$) as a metallographic etchant for steel and cast iron has been known for some years, the etching effects produced by this reagent being essentially the same as those obtained by heat-tinting at higher temperatures.

Some of the advantages claimed for sodium bisulphite as an etchant are that it enhances contrast between adjacent ferrite grains in low-carbon steels, that it defines austenite grains, martensite, and undissolved carbides in quenched high-carbon steels, that it is superior to saturated picral in revealing lines of deformation and other fine details of the structure of broken test specimens, that it is highly sensitive to chemical segregations, and that it brings out clearly the carbide network in carburizing tests. In addition, it has been found that, when applied to low-alloy, high-strength steels, sodium bisulphite tints the grains in three different colours which are reproduced as three distinct shades of grey when the steel is photographed in black and white. Also, as distinct from 5% nital, sodium bisulphite, like Stead's reagent, reveals phosphorus segregations and brings out at the grain boundaries of cold-reduced rimmed steel certain white bands, slightly raised from the surface, which disappear on normalizing.

According to the authors, another quite remarkable and useful property of this reagent, not previously discussed, is its ability to etch or darken untempered martensite at least as rapidly as it etches practically all other microstructures, including some tempered martensites. Thus, for comparison, Fig. 1 is a photomicrograph of a plain carbon eutectoid steel etched with saturated picral for 15 sec, while Fig. 2 is a photomicrograph of the same steel etched with an aqueous solution of sodium bisulphite for 10 sec and shows that both martensite and pearlite are etched at the same rate. In structures consisting of fast-etching fine nodular pearlite and upper bainite in a martensite matrix, sodium bisulphite brings out the needle structure of martensite without overetching the fine pearlite or bainite.

Sodium bisulphite is also useful in conjunction with other etchants. Thus, for example, in the specific case of a steel containing 0·18% C, 0·67% Mn, and 1·07% Ni, the structure shown in Figs. 3 and 4 was produced by partial isothermal transformation at 1050°F and consists of dark areas of what may be called fine pearlite and comparatively large needles of Widmanstätten ferrite in a matrix of martensite. The etching problem presented by this type of structure is that, while conventional etchants produce sufficient contrast to differentiate ferrite from martensite, they also invariably blacken the fine pearlite, thereby obliterating all details in the structure. In this particular instance, the problem was solved by first etching lightly with saturated picral (Fig. 3) and then superimposing a light etch with an aqueous solution of sodium bisulphite (Fig. 4), which does not attack excessively the fine pearlitic structure, but mainly confines its action to the martensitic matrix.

Sodium bisulphite is also useful in the study of the

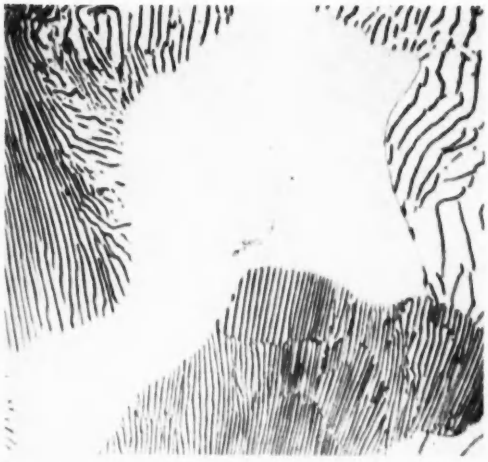

Fig. 1. Photomicrograph of a plain carbon eutectoid steel etched with saturated picral for 15 sec. (X800)

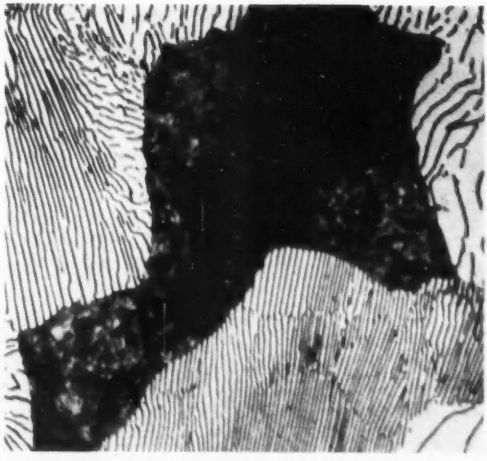

Fig. 2. Photomicrograph of a plain carbon eutectoid steel etched in with sodium bisulphite for 10 sec. (X800)

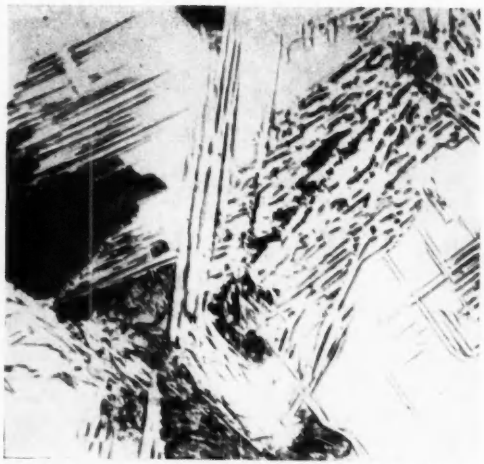

Fig. 3. Photomicrograph of a steel containing 0·18% C, 0·67% Mn, and 1·07% Ni, lightly etched with saturated picral only. (X800)

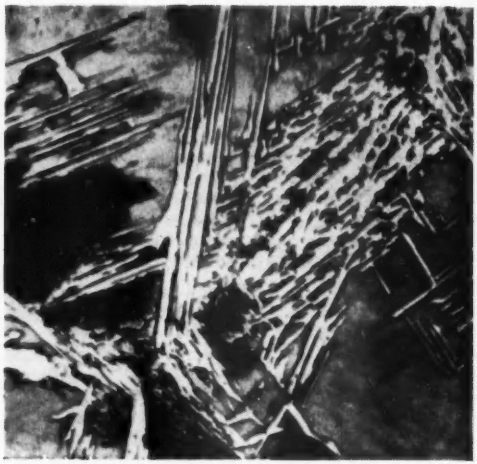

Fig. 4. Photomicrograph of the same specimen shown in Fig. 3, after superimposition of a light sodium bisulphite etch on the picral etch. (X800)

isothermal transformation of low-carbon steels. The technique consists of etching with picral, followed by 1% nital and sodium bisulphite, clearly defining the various transformation products found in such steels, and helping to distinguish ferrite from low-carbon martensite.

Because aqueous solutions often do not evenly wet highly polished metallic surfaces, it is desirable to add a very small amount of a suitable wetting agent to the solution (e.g., 1 drop per 100 cc of solution). Also, good polishing techniques are necessary when etching with sodium bisulphite, because this reagent brings out fine scratches which are not visible after etching with picral or nital solutions. For darkening martensite, the concentration of sodium bisulphite in solution is not critical, good results being obtained with concentrations ranging from 10 to 35%.

Finally, it may be said that, although aqueous solutions of potassium metabisulphite and of ammonium persulphate will also etch steel, they do not appear to possess any advantage over sodium bisulphite.

Etching Uranium for Bright-Field Examination

Routine micro-examination of uranium under polarized light has certain disadvantages, such as the fact that the grains appear to assume different sizes when the specimen is rotated. It is therefore of interest to note that a chemical etchant has now been developed which will reveal the grain structure of uranium under bright-field illumination and which provides a simpler and more rapid technique than that of bright-field examination of uranium prepared by cathode vacuum etching.

The new etchant is composed of 130 millilitres of concentrated H_2SO_4, 50 millilitres of H_2O_2 (30% by weight), 0·2 gram of Na_2SiF_6, and 60 millitres of H_2O. The specimen should be immersed in the etchant immediately after the H_2SO_4 is added, the etching time being approximately 30 sec. Because of the highly exothermic reaction between H_2SO_4 and H_2O_2, the temperature of the solution rises to about 285° F and boils for about 3 min

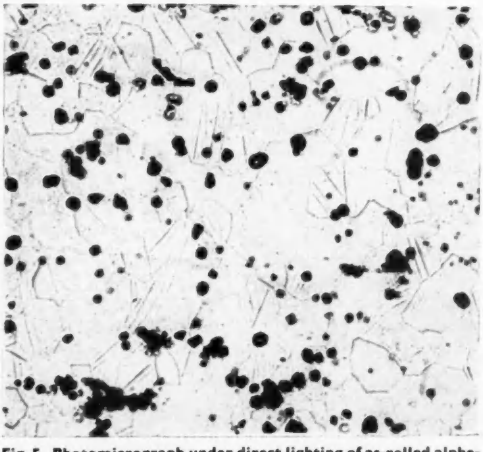

Fig. 5. Photomicrograph under direct lighting of as-rolled alpha-uranium, etched with the new reagent. (X250)

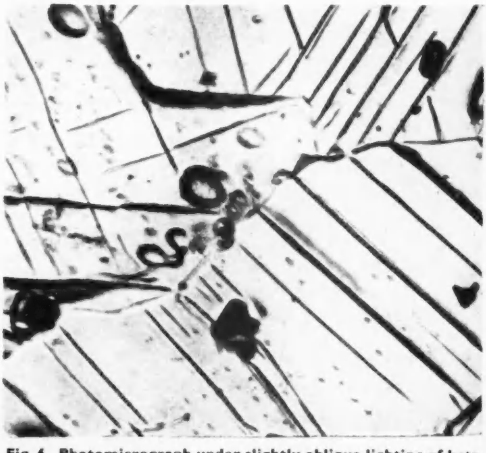

Fig. 6. Photomicrograph under slightly oblique lighting of beta-transformed uranium, etched with the new reagent. (X500)

after the H_2SO_4 is added. After this 3-min period, the solution will attack the uranium to some extent, but will not etch it satisfactorily. The Na_2SiF_6 forms a complex with the free uranium ions, thereby preventing the formation of salt crystals on the surface of the specimen.

Although satisfactory etching can be obtained over a wide range of grain sizes with the above etchant composition, the water content should be reduced by about 25 millilitres when etching specimens with very small grains, the effect being less pitting on small grains, which appear to etch at a slightly slower rate than large grains. During etching, a thin oxide film forms on the specimen, but this can be removed by electropolishing with the same electrolyte and conditions normally recommended for uranium.

Figs. 5 and 6 show photomicrographs typical of those obtained from specimens of as-rolled and beta-transformed uranium which have been chemically etched.

Damping Tapes for Vibration Control

By E. E. UNGAR

From *Product Engineering*, U.S.A.,
Vol. 31, No. 4, January 25, 1960,
pp. 57–62, 6 illustrations

THE mastic undercoating applied to an automobile reduces noise because of visco-elastic damping. When the damping layer is increased, e.g., by a properly designed tape, the result is a new and effective way of sharply reducing the vibration stresses in a system, particularly at resonance.

Such a tape allows more freedom when designing elastic structures subject to forces over a wide frequency band, so that natural frequencies need not be kept outside the exciting frequency range, and the extra stiffening normally added to brace against resistance loads can be reduced or eliminated. To these advantages must be added the versatility of damping tapes as an energy-dissipation technique, inasmuch as they can be made in any easy-to-apply form and that several tapes can be superimposed to achieve the correct damping effect, without having to design a special tape for each application. In addition, high damping at low frequencies (usually the most troublesome) becomes possible, good damping can be obtained over a reasonably wide range of frequencies (from below 40 to over 600 cps), and the damping effect can be predicted reliably from theory, thereby reducing trial-and-error development to a minimum. Also, if desired, thermal barriers can be built in.

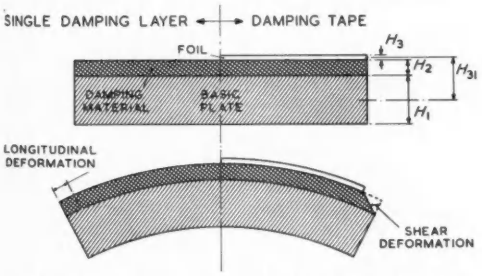

Fig. 1. Comparison of energy-absorbing action for (left) a single damping layer, and (right) a tape comprising a damping layer plus a metal foil.

Many damping methods for plate and shell structures are theoretically possible, the main practical problem being to obtain a sufficient amount of damping without excess weight and undue mechanical complexity. One of the most obvious means of damping employs friction between two surfaces in relative motion, and this is sometimes effected with fibrous or highly viscous materials between the two contacting surfaces.

Capitalizing on the inherent damping in a highly dissipative material is a less obvious way. Such a material may be applied in a single layer, as with automobile undercoatings. This type of coating absorbs energy by extending and contracting longitudinally when the baseplate bends, as shown in the left half of Fig. 1. The amount of energy absorbed per oscillation depends on the mean longitudinal strain induced in the coating, and this strain increases with the thickness of the coating application. The degree of damping is therefore limited by thickness and weight restrictions.

As an alternative technique, the strain in the dissipative material (and thus the damping it provides) can be increased if the coating is applied on top of a " spacing layer "—stiff in shear, but not too stiff in extension. Effectiveness here clearly depends on the thickness and stiffness of the spacing layer. Though this alternative can reduce weight, excess thickness and complexity are still problems.

Damping tapes are a better answer. When a thin, extensionally stiff foil is placed on top of a thin layer of dissipative material (an adhesive, for example), this material is subjected to large shear strains, as shown in the right half of Fig. 1, producing considerable damping. Such a composite material can be made relatively thin and light, and can be produced as an easily applied adhesive " tape ".

The damping effect of a damping tape on a plate has been investigated extensively. For the common tapes, usually quite thin compared with the baseplates, damping effectiveness d obeys the approximate relation

$$d = \frac{12 \dfrac{E_3}{E_1}\dfrac{H_3}{H_1}\left(\dfrac{H_{31}}{H_1}\right)^2 \beta g}{1 + 2g + (1 + \beta^2)\, g^2} \quad \ldots \ldots \quad (1)$$

where the dimensions H_1, H_3, H_{31} are as shown in Fig. 1, E_1 and E_3 are the moduli of elasticity of the basic plate and the tape foil respectively, and β is the loss factor of the dissipative material. Various damping materials are available, including polypropylene, polytrifluorochlorethylene, polyisobutelene, polyvinylchloride, foamed

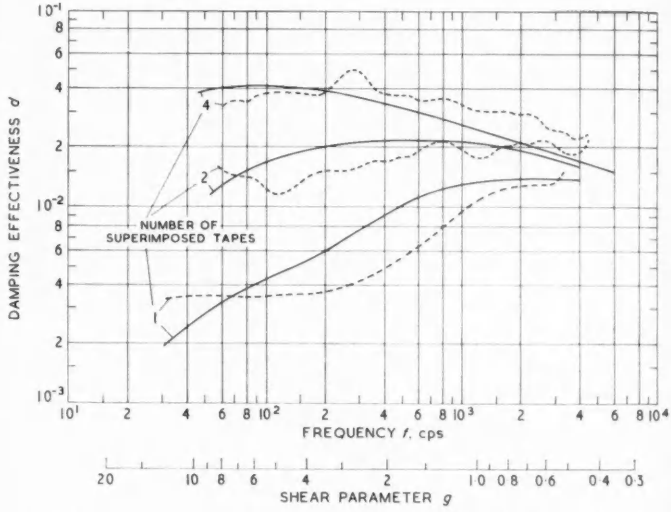

Fig. 3. Damping effectiveness d as a function of frequency f and shear parameter g, showing correlation of theoretical and experimental datawith various numbers of superimposed tapes

Solid lines: Theoretical results.
Dotted lines: Experimental results.
Basic plate: 0·125-in. aluminium.
Single tape: 0·003-in. aluminium, 0·0025-in. adhesive.

polyvinylchloride, and a number of synthetic rubbers, typical good damping materials having a loss factor β between approximately 0·2 and 2·0. The damping effectiveness d is one of many common measures of damping. In eq. (1), g is a dimensionless " shear parameter " which governs damping and is given by

$$g = \frac{G\,(B/M)^{\frac{1}{2}}}{\omega\, E_3\, H_3\, H_2} = \frac{G\, H_1}{4\pi f E_3\, H_3\, H_2}\left(\frac{E_1}{2\sigma_1}\right)^{\frac{1}{2}} \quad .. \quad (2)$$

where G is the shear modulus and H_2 the thickness of the adhesive dissipative layer; B is the flexural rigidity and M the mass per unit area of the plate, ω is the angular frequency of the oscillation, f is the frequency, and σ_1 is the density of the plate. For plates made of steel and aluminium, eq. (2) reduces to

$$g = \frac{8600}{f} \times \frac{G\, H_1}{E_3\, H_3\, H_2} \quad .. \quad .. \quad (3)$$

The shear parameter g is also capable of physical interpretation. Thus, it can be shown that g depends on the ratio of the vibration wavelength to the distance within which a localized shear disturbance decays to a certain fraction of its value. Thus, g is related (in a complex way) to how much shear a flexural oscillation produces.

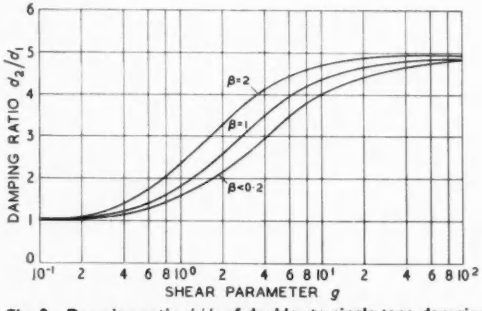

Fig. 2. Damping ratio d_2/d_1 of double- to single-tape damping for various values of loss factor β, as a function of shear parameter g.

From Eq (1), for a value of β of unity, damping effectiveness d varies nearly linearly with g for small values of g (high frequencies), reaches a maximum at $g = 1/(1+\beta^2)^{\frac{1}{2}}$, and varies nearly inversely with g for large values of g (low frequencies). Eq. (1) may be used as the basis for designing damping tapes. In practice, however, the effect of frequency and temperature on β and G for the dissipative material must be accounted for. The properties of the foil and plate can also be affected.

When designing damping tapes for massive structures, the calculated foil thicknesses are often so great that the tapes would be difficult to handle. Two tapes can then be specified, one each side of the plate, each giving half the required damping. If one side of the plate must be left uncovered, a satisfactory answer is a double-tape arrangement, i.e., one tape placed on top of another just like it. Damping behaviour obtained by this superimposition is different from those obtained with tapes on opposite sides of the plate. Thus, two tapes behave like a single tape at high frequencies (low values of g) but are much superior to a single tape at low frequencies. For both, it is possible to design tapes to produce significant damping over a reasonably wide frequency range of interest. The ratio d_2/d_1 of double to single damping where d_2 is the damping effectiveness with two tapes and d_1 with one tape, is shown in Fig. 2 for various values of loss factor β, and can be used with eqs. (1) and (2) to design double damping tapes.

The damping action of two superimposed tapes is very nearly that of a single tape with a foil thickness equal to the sum of the foil thicknesses of the individual tapes, but with a damping material thickness of only one of the tapes. Equally important is the fact that this relation also appears to hold if the component tapes are of different foil thicknesses, and for more than two tapes. These simplifications hold as long as the total thickness of the tapes is less than about one-fourth of the basic-plate thickness.

Designing with multiple tapes gives maximum flexibility, considering the limited number of tapes available. For example, Fig. 3 shows how a single tape superimposed four times can multiply damping effectiveness nearly ten times at low frequencies. It also shows the relatively good agreement obtained between theoretical results and experimental data, although there are some inherent experimental difficulties.

Despite the wide use of pressure-sensitive tapes, commercial manufacture of damping tapes in variety is

(Concluded on page 139)

The "Logmotor" Cylindrical Brushless Variable-Speed Induction Motor

By E. R. LAITHWAITE*, M.Sc., Ph.D., A.M.I.E.E., Mem. A.I.E.E.

THE synchronous speed ω_s of an induction motor is governed only by the frequency of the supply and the number of poles. The power supplied by the stator to the rotor is given by $T\omega_s$, where T is the torque, while the output from the machine is $T\omega$, ω being the actual rotor speed. It follows that the quantity $(T\omega_s - T\omega)$ is equal to the rotor loss and hence the fractional slip σ, which is defined by

$$\sigma = \frac{\omega_s - \omega}{\omega_s} = \frac{T\omega_s - T\omega}{T\omega_s} = \frac{\text{rotor loss}}{\text{rotor input}}$$

The rotor efficiency is therefore equal to $1 - \sigma$ (i.e., to ω/ω_s). Efficient speed control of induction motors can be obtained without changing the synchronous speed, if the rotor power loss can be returned to the supply, but this involves frequency conversion and generally necessitates the use of a commutator.

Pole-changing methods provide a means of changing the synchronous speed in discrete steps. Until quite recently a single stator winding could only be made to produce a 2:1 change in speed. For any other speed change, separate windings were needed in the stator reducing the available copper space in the slots. Recent developments in pole-changing motors first yielded a 3:1 pole-changing motor[1,2] and subsequently a variety of speed changes covering a wide range of synchronous speeds, always corresponding to even integral pole numbers.[3,4]

At the same time, some progress was made in the development of a continuously adjustable pole-pitch machine with the discovery of the angled-field principle[5] and the development of the spherical motor[6,7], in which variation of pitch was obtained by mechanically changing the angle between the direction of motion of the field and that of the rotor. In a recent article[8] it was suggested that the difficulty of manufacturing the spherical motor might be overcome, without abandoning its principle, by the use of phase-shifters supplying current to helical windings on a cylindrical machine. This structure was also, however, unconventional, but gave rise to a new approach to the problem of continuous pole-pitch adjustment.

The Problem of Pole-Stretching

In a polyphase induction motor with a distributed winding, the phase difference between currents in adjacent slots is more or less uniform around the periphery. For example, a 4-pole machine with 48 slots has 12 slots per pole, and the phase of the effective stator current advances 15 deg. per slot. Conversion of this machine to an 8-pole motor involves the changing of the phase increment per slot from 15 to 30 deg.

The problem of providing continuous adjustment of synchronous speed is twofold, i.e., (1) means must be provided for changing the phase increment per slot smoothly through any number of degrees, and (2) the machine must be capable of running at a speed corresponding to a non-integral number of poles. If, for example, the 48-slot machine were capable of continuous phase adjustment and the phase increment per slot were set to 17 deg., beginning with slots numbers 1 to 2, then the phase in slot 48 would be 816 deg., i.e., 4 pole-pitches plus 96 deg., and there would be a phase discontinuity of 96 deg. between slot numbers 48 and 1. In this condition, the machine would not behave in the desired manner, and would run up as a 6-pole machine and also as a 4-pole machine, providing that it is first driven up to the higher speed or above. One method of eliminating this effect is to provide a break in the magnetic circuit, as shown in the diagrammatic view in Fig. 1 of a phase-controlled motor. In this way, by omitting a sector from the motor stator, the rotor flux carried out from the end of the stator from which the rotor bars emerge can decay to a very small value before re-entry, and its phase is therefore of no consequence. However, breaking the magnetic circuit in this way places some restriction on the design of the machine. The theory of the induction motor with an open magnetic circuit has been developed in some detail[6,7,9,10], and the two principal limitations on its characteristics may be stated as follows:

(1) Each rotor bar suffers transients twice per revolution, resulting in a non-uniform distribution of flux around the periphery.

(2) Extra losses are incurred by the transients, unless the machine is run at a slip given by $\sigma = 2/(n+2)$, where n is the number of poles around the active arc of the stator.

In practice, the peak efficiency occurs at a slip between the values $1/(n+1)$ and $2/(n+2)$, but its value can never exceed $n/(n+1)$. The number of poles on a reasonably good machine must therefore exceed four. Nevertheless, it is possible to design good motors of this type, although they are essentially multi-polar.

The problem of adjustment of phase increment is illustrated in Fig. 2, in which Fig. 2a is a vectorial representation of the current per slot for one particular pole pitch, an increase of pitch resulting in the need to make the phase changes shown in Fig. 2b. This appears to involve the use of a variable phase supply with as many phases as there are stator slots, each capable of producing a different phase shift, and this is, in fact, the method of pole-stretching used in the cylindrical brushless variable-speed induction motor, designated the "logmotor", described in this paper.

Basic Principle of the "Logmotor"

The "logmotor" consists of a special type of phase-shifting regulator which feeds the stator of an arch-type squirrel-cage induction motor of the type shown in Fig. 1. The phase-shifting system could consist of a large number of conventional phase shifters (the same number as the number of slots in the arch motor stator), all geared together to give the appropriate phase shift $(\beta - \alpha)$, $2(\beta - \alpha)$, $3(\beta - \alpha)$ . . . etc., as shown in Fig. 2. If the phase shifters were made to have different pole numbers

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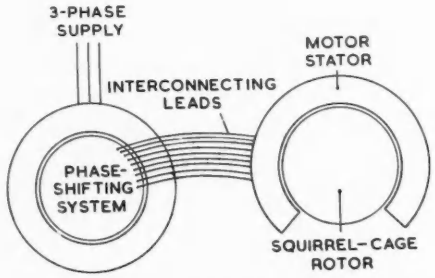

Fig. 1. Diagrammatic representation of a phase-controlled motor.

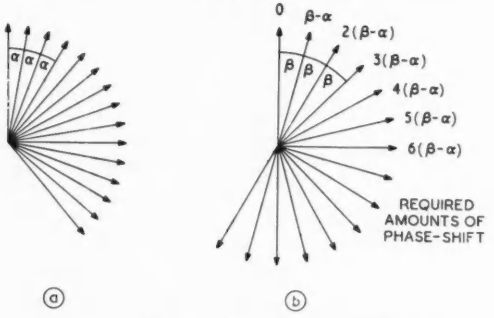

Fig. 2. Pole-stretching by phase adjustment.

(the electrical equivalent of gearing) they could all be mounted on a common shaft. Alternatively, a single phase shifter could be designed having sets of coils of different pitch, covering different arcs around the periphery, as shown in the developed diagram in Fig. 3. The disadvantage of such a system is that very little movement is possible before one set of primary coils overlaps the wrong kind of secondary coils. The inherent limitation in the system shown in Fig. 3 is that each part of the secondary winding has a coil pitch associated with it.

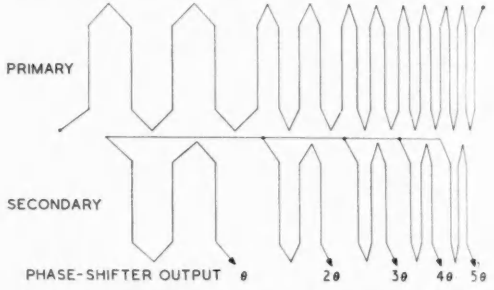

Fig. 3. Developed diagram of a multi-channel output phase shifter.

In the arrangement shown developed in Fig. 4a, successive primary coil pitches constitute a logarithmic sequence, and the secondary (Fig. 4b) consists of single conductors in logarithmically spaced slots, all the conductors being connected to a common conducting ring at one end. The free ends form a polyphase system of supply, the phase increment between the e.m.f.'s in adjacent conductors being uniform. The primary and secondary slots correspond to the numbers on the *C* and

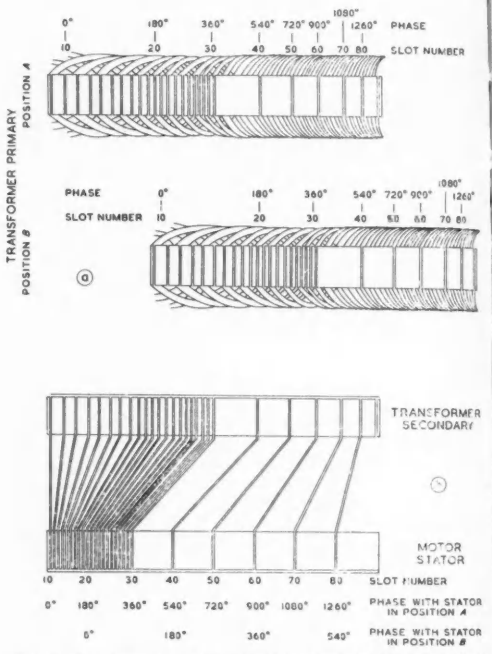

Fig. 4. Arrangement of the logarithmic windings in the phase shifter.

D scales of a slide-rule, so that, when one is moved relative to the other, i.e., from position *A* to position *B* in Fig. 4a, the phase increment between every pair of adjacent secondary conductors is increased by the same amount. In the simple case in Fig. 4, the phase increment is doubled, but it will be appreciated that any non-integral increase is equally possible. It has been shown that logarithmic distribution of conductors is the only system having this property[11].

The free ends of the secondary conductors can be passed directly through equally spaced slots in the motor-stator and connected to a common ring at the far end as shown in Fig. 5, which also illustrates the flow of current in the system of conductors of the phase-shifter secondary and motor stator for one particular setting of the phase shifter, the motor rotor consisting of a conventional squirrel cage.

When a change in speed is demanded by moving the phase-shifter primary relative to the secondary, a system such as that shown in Fig. 5 would be left with one end of the primary overhanging the secondary, and the opposite end of the secondary not opposed by any primary winding. It is easier to demonstrate the effects of these overhangs by considering two different types of system. In the first system, shown diagrammatically in Fig. 6a, the primary winding is made longer than the secondary, and the latter is allowed to move only within the confines of the primary, as shown in positions I and II. It can be seen that the effect of primary-secondary movement is to produce a variable number of poles on a fixed arc of the motor stator, and such a machine is said to have a *varien* operation. In the second system, shown in Fig. 6b, the secondary is longer than the primary, and field-speed variation is obtained by varying the length of arc of the motor stator occupied by a fixed number of

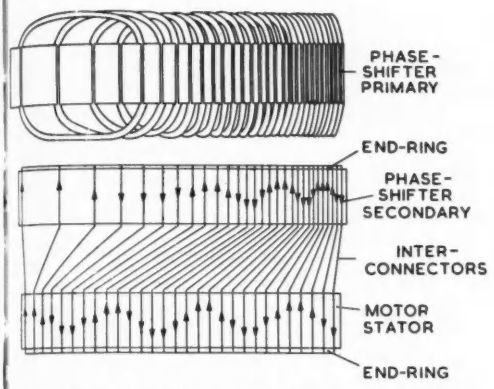

Fig. 5. Arrangement of conductors and current distribution in a logmotor.

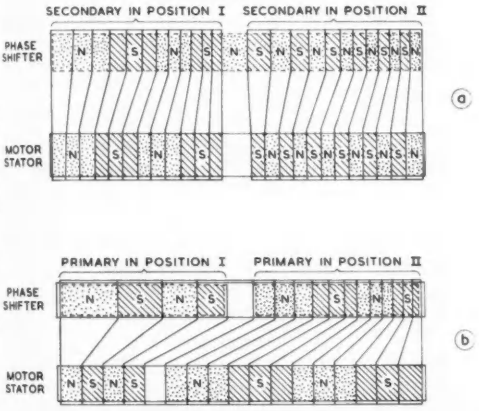

Fig. 6. Effect of relative extents of the phase-shifter primary and secondary windings with (a) *varien* operation, and (b) *variarc* operation.

poles, i.e., the number on the primary winding. Moreover, the energized arc of the motor stator does not only stretch, but changes its position around the motor periphery. Such a machine is said to have a *variarc* operation. The choice of *varien* and *variarc* operation largely determines the characteristics of the motor, as discussed later. Combinations of *varien* and *variarc* operation are clearly possible.

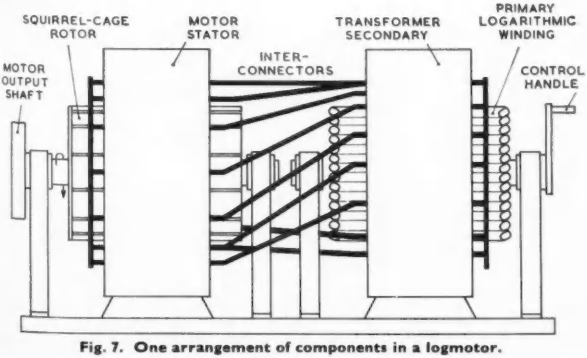

Fig. 7. One arrangement of components in a logmotor.

Design Aspects of the Logmotor

All the features outlined in the previous section must be referred to a cylindrical structure, a convenient layout of phase shifter and motor being shown in Fig. 7, in which the primary winding of the phase shifter is made the rotor of one half of the machine and is fed through flexible leads. Interconnectors should be kept as short as possible between the machines to minimize copper losses. An alternative arrangement to that shown in Fig. 7 consists of inverting the phase shifter so that the rotor carries the interconnectors which are carried through the motor "rotor" slots, the motor "rotor" in this case being the stationary member, and the outside member the moving part carrying the squirrel cage. This alternative form has the inherent difficulties of mounting the moving member of the motor, but has the advantage that rotation of the pair of inner members only is necessary for speed control, and no flexible leads are required.

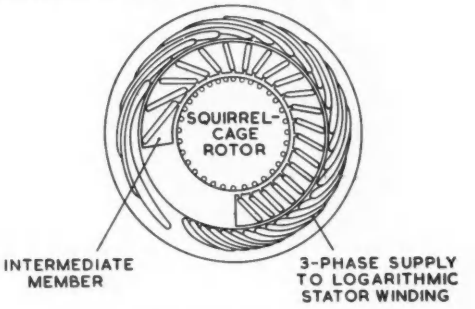

Fig. 8. Concentric arrangement of a logmotor.

Still another alternative structure is shown in Fig. 8, and comprises a concentric version employing *varien* operation. The outside stator carries the logarithmic primary winding, and the outside surface of the intermediate annular member carries the secondary bars, while its inner surface comprises the motor stator. The interconnectors thus become the end turns of the annular member. Again, no flexible leads are required, the intermediate member providing speed control. Fig. 8 illustrates several of the design problems more clearly than Fig. 7. In *varien* operation, the overhanging primary must not be left to drive flux into a closed magnetic circuit, since the logarithmic winding is series-connected and the part outside the limits of the secondary presents a high impedance to the primary current. The secondary iron can be cut away in this region or, alternatively, its slots can be filled with a conducting grid, like a section of a squirrel cage. In the same way as removal of the iron, this also reflects a low impedance into the primary, although some extra copper loss in the grid is incurred in the process.

In *variarc* operation the inactive arc varies from setting to setting, so that the iron of the motor stator cannot be cut away. In this case, the unused arc of the phase-shifter primary must be cut away or fitted with a short-circuiting grid, automatically reflecting a low impedance across the appropriate motor arc via the interconnectors.

For each design of primary winding and

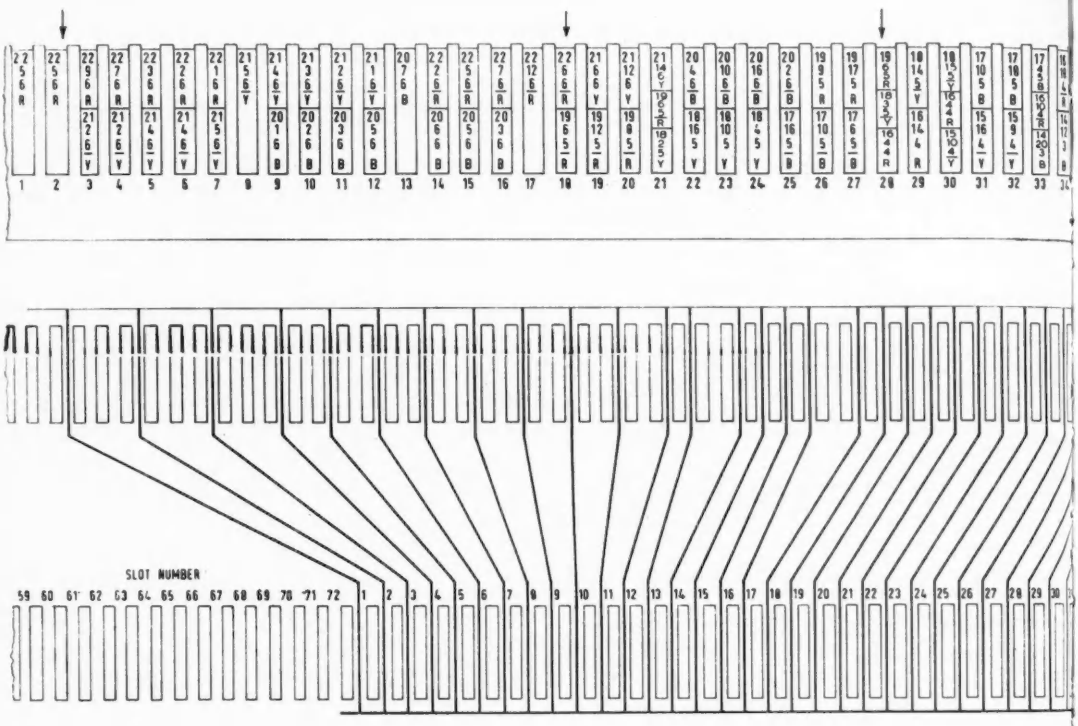

Fig. 9. Complete winding diagram of a logm

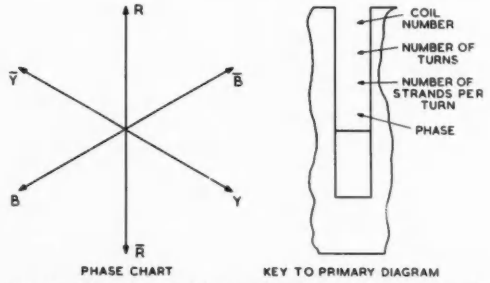

Fig. 10. Phase chart and key to the winding diagram of Fig. 9.

interconnectors* there is a limit to the amount of speed variation which is possible before one extremity of the primary overlaps the wrong end of the interconnectors, and this can occur in either direction. One such overlap has a negligible effect, while the other is intolerable. Fig. 5 illustrates the problem: The right-hand end of the primary carries a high current loading and, if this overlaps the left-hand end of the secondary, this high current loading is reflected into the secondary, further compressed by the interconnectors, and produces a very high loading of a completely wrong phase increment in the motor stator. If, on the other hand, the low current loading of the left-hand end of the primary overlaps secondary bars which are being expanded by the interconnectors, the motor-stator currents in this region, wrongly phased though they are, are of such a low value as to have a negligible effect on performance. This has already been verified by experiment and is of use to designers, since it makes it possible to extend the speed range without reducing active arc.

As regards the windings themselves, the interconnectors, being single conductors of considerable section, are liable to suffer from skin effect if made from solid bar. They are therefore constructed from stranded wire, preferably of rectangular section, suitably transposed. The conductors of the phase-shifter secondary need not be housed in special logarithmic slotting, conventional uniform slotting being practical, with the bars placed in the nearest appropriate slot. Some reduction in interconnector length can be obtained by shifting some of the responsibility for the logarithmic-to-linear conversion on to the motor stator. This technique is illustrated in the complete winding diagram of a logmotor shown in Fig. 9 for which Fig. 10 shows the corresponding phase chart and key. A large number of interconnectors are simple straight connections.

The primary winding can also be designed to fill a uniformly slotted structure, thus reducing all iron parts to parts of conventional construction. The coils of the primary are rather complex, since the turns of one coil may occupy, say, 3 slots on one coil side and 5 slots on the other. As the coil pitches increase, the number of slots per pole per phase increases and each slot contains fewer turns. The number of strands in each conductor can therefore be increased to fill the slot and reduce copper loss in this area. The output of the machine, however, will always be limited by the highest current loading, i.e., the small pole-pitch end of the primary.

* The logarithmic spread of the interconnectors is matched to that of the primary winding. The interconnectors can be regarded as taking the anti-log of the primary phase distribution.

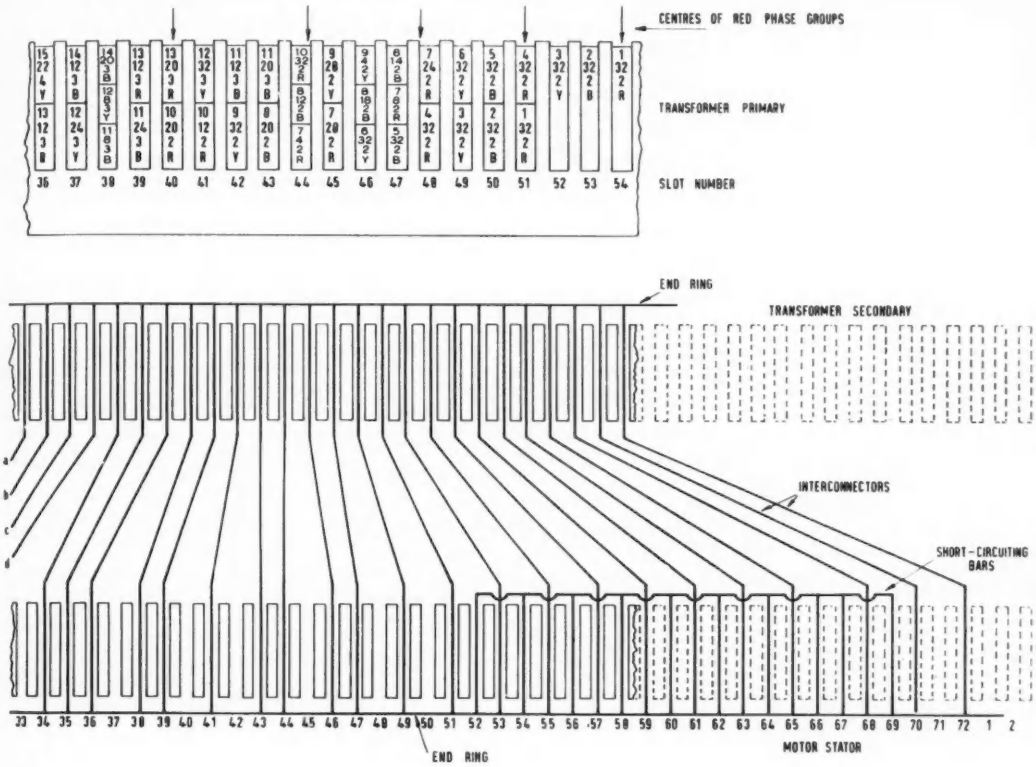
CENTRES OF RED PHASE GROUPS
TRANSFORMER PRIMARY
SLOT NUMBER
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54
END RING
TRANSFORMER SECONDARY
INTERCONNECTORS
SHORT-CIRCUITING BARS
a
b
c
33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 1 2
END RING
MOTOR STATOR

Fig. 9 shows the disposition of primary conductors in a typical logmotor design.

The primary and secondary of the phase shifters can with advantage be designed to have equal numbers of slots. In this way, the coupling is excellent when the teeth are in register, and the machine should then be run only in this condition. Continuous speed adjustment is thus replaced by a large number of discrete steps, so large, in fact, as to be sufficiently near to continuous adjustment, as required for most purposes, and excessive zig-zag leakage can be avoided. Zig-zag leakage can be reduced still further by the elimination of empty slots on the phase-shifter secondary. An empty slot allows the primary current which it faces to drive what might be called a zig-zag flux, not across the slot opening, but around the back of the empty slot, where the reluctance is low. As interconnectors are made up of stranded wire, they can be split and some proportion of the conductor on either side fed through each empty slot.

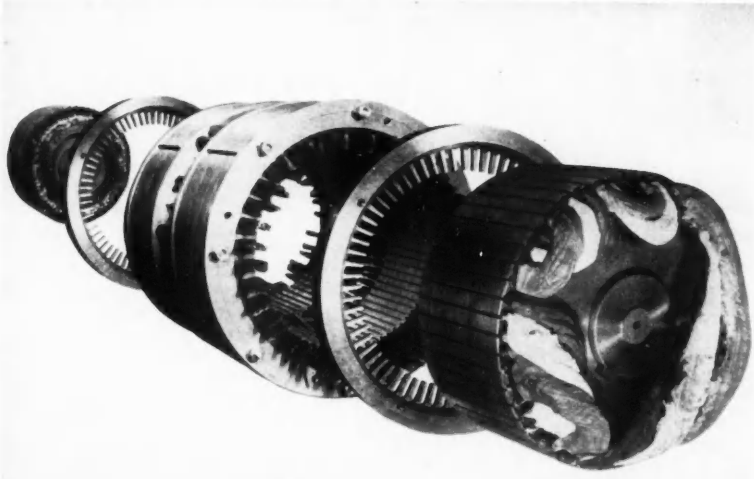

Fig. 11. Exploded view of the experimental logmotor.

The design of a logmotor is basically the design of a transformer and a short-stator induction machine in series. The transformer is, of course, of unusual shape and winding arrangement and, in calculating fluxes, each pair of interconnectors can be regarded as a "flux funnel", collecting all the flux in the tooth or teeth embraced on the motor stator and transferring it to the tooth or teeth on the transformer secondary. The design of short-stator machines is quite different from that of conventional motors, and space does not permit a complete design technique to be included in this paper A complete procedure has, however, been described elsewhere[7].

Fig. 11 shows an exploded view of a completed logmotor, the general layout of which is of the form illustrated in Fig. 7. The most successful experimental machine built so far has its motor rotor mounted on a shaft which passes right through the machine, transformer primary being mounted on separate bearings on this shaft.

Performance of a Logmotor

With *varien* operation, the characteristics of a logmotor are that it provides an output proportional to the cube of the speed when supplied from a constant-voltage source. The current drawn from the source is proportional to the cube of the velocity whilst the airgap flux density is approximately constant at all speeds. Thus, the iron remains fully loaded at all speeds, while the conductors are under-loaded at all speeds except at maximum speed. The core depth must be such as to accommodate the flux for the maximum pole-pitch setting.

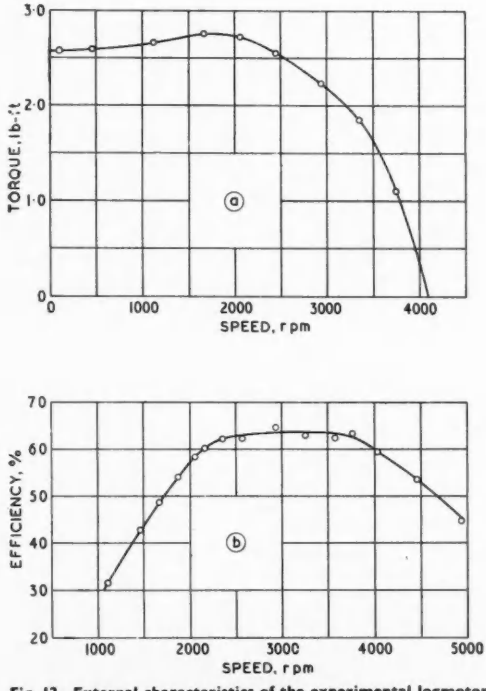

Fig. 12. External characteristics of the experimental logmotor with *variarc* operation.

Variarc operation, on the other hand, produces an output proportional to speed, current loading being proportional to speed and the gap flux density inversely proportional to speed. The flux density in the core is thus constant, but the teeth must be wide enough to accommodate the flux at the lowest speed setting. Although the product of core flux and current loading is constant, this type of machine has reduced power at reduced speed as the result of using a smaller energized arc. With both *variarc* and *varien* operation, at any setting of the primary, the logmotor has a speed-torque curve similar to that of a normal high-resistance-rotor induction motor with the appropriate number of poles, a typical curve for one particular setting of a small *variarc* 400-cps test machine being shown in Fig. 12a, and the variation in peak efficiency for various settings in Fig. 12b, the drop in efficiency at each end of the range being due to overlap. Like the spherical motor, the logmotor is essentially a multi-polar machine, being subject to the short stator limitation of a working slip greater than $1/(n+1)$, so that small machines with reasonable speed ranges cannot be made to have high efficiencies.

A 120-hp logmotor is being designed at the present time, and it is expected that efficiencies comparable with those of Ward-Leonard sets of equal rating will be obtained. Development work is in too early a stage for it to be possible to estimate the cost of logmotors and to compare them with competitive systems.

In the preparation of this article, the author has made use of some of the information and diagrams in the paper by Prof. F. C. Williams, Dr. E. R. Laithwaite, and Messrs. J. F. Eastham and L. S. Piggott entitled "The Logmotor—a Cylindrical Brushless Variable-Speed Induction Motor", which was first published by the Institution of Electrical Engineers as Paper No. 3149U in February, 1960, and will be republished in Part A of the Proceedings of the Institution.

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Available-Enthalpy or "Exergy" Diagrams for Combustion Gases

By Z. RANT

From *Brennstoff-Wärme-Kraft (BWK)*, Germany,
Vol. 12, No. 1, January 5, 1960,
pp. 1–8, 7 illustrations

ENERGY can be divided into two parts, one of which is mechanical and hence convertible, while the other is not convertible, and either of these constituent parts can be zero. The quantity of energy available for mechanical work can be termed " available enthalpy" or " exergy ", i.e., usable energy, as proposed by the author[1] and other investigators.

Thus, for example, the available enthalpy e of a quantity of heat q supplied at a temperature T can be expressed as

$$e = q(T - T_0)/T \qquad (1)$$

where T_0 is the ambient temperature. With regard to the energy contained in a substance, the available enthalpy e is given by

$$e = i_1 - i_0 - T_0(s_1 - s_0) \qquad (2)$$

where i_1 and s_1 are respectively the total heat or total enthalpy and the entropy of the substance, both in the initial state, and i_0 and s_0 are respectively the total heat or total enthalpy and the entropy of the substance, both under ambient conditions of temperature T_0 and pressure p_0.

In addition, it is possible to define a quality factor ζ for a process on an available-enthalpy or exergy basis as

$$\zeta = E_2/E_1 \qquad (3)$$

where E_1 is the initial available enthalpy of the substance, and E_2 is its final available enthalpy.

A correct and complete assessment of an energy process on the basis of available enthalpies is made in two stages, in the first of which the paths followed by the energy and the quantities of energy are determined, using the first law of thermodynamics, with the results suitably represented in a heat-balance diagram. The second law of thermodynamics is then applied, the flow of available enthalpy along the energy paths is determined, and the quality factor ζ is evaluated. Large losses of available enthalpy occur at weak points in the process, and these require investigation to find out whether they can be reduced (reduction of irreversible quantities) by economical means, without making an " improvement " that will cause a deterioration of conditions at some other position. The flow of available enthalpy can also be represented in a flow diagram[2].

Although some technical processes have been investigated from the point of view of available enthalpy,[3-9] these methods have not as yet been largely applied in practice, because of the extensive computations required. It is therefore the object of this paper to provide a simplified procedure with ready-made diagrams, in order to facilitate the analysis of energy processes.

The large flow quantities and continuously increasing size of steam power-plant are incitements to further improvements and closer analyses. The available-enthalpy flow can be followed along the same path as the flow of energy, i.e., the fuel, combustion gases, steam and electric current. An analogy between voltage and available enthalpy has already been derived[9] for this purpose. An attempt will now be made to fulfil the requirements as regards accuracy of analysis and, at the same time, to provide a simple procedure for evaluation.

Available Enthalpy of Fuels

The available enthalpy of fuels can be calculated with the aid of eq. (2), on the basis of a stoichiometric combination of oxygen with the combustible constituents of the fuel. The value of $i_1 - i_0$ is that of the total heat of the reaction, s_1 is the sum of the absolute entropies of the actual components of the fuel taking part in the reaction, and s_0 is the sum of the absolute entropies of the reaction products at ambient temperature T_0.

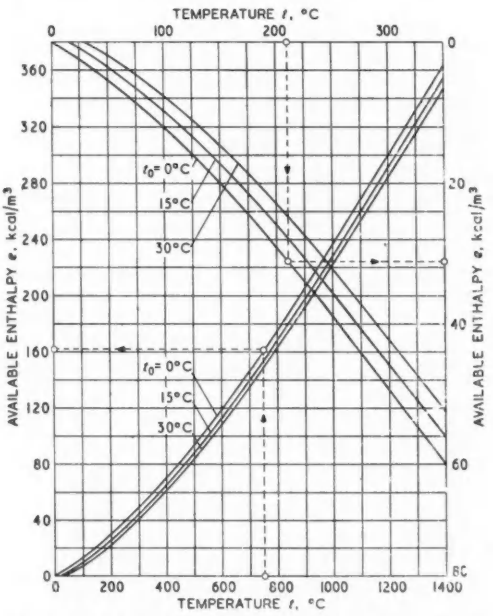

Fig. 1. Available enthalpy e of air as a function of temperature t at an absolute pressure of 1 atm and different ambient temperatures t_0.

In a previous paper by the author[10], it has been shown that simple relationships, giving sufficiently accurate approximations, are valid between the available enthalpy e and the upper and lower calorific values H_U and H_L of fuels. For coals,

$$e \cong H_{LC} \qquad (4)$$

where H_{LC} is the lower calorific value of the combustible substances in the coal. If w is the moisture content of coal per unit mass, and r is the heat of evaporation of water, then $H_{LC} = H_L + wr$.

For liquid hydrocarbons with more than one carbon atom per molecule,

$$e = 0{\cdot}975\ H_U \qquad (5)$$

Finally, for gaseous hydrocarbons with more than one carbon atom per molecule,

$$e = 0{\cdot}95\ H_U \qquad (6)$$

Available Enthalpy of Air and Combustion Gases

Air at ambient temperature has no available enthalpy, but preheated air introduces into the combustion process an amount of available enthalpy which must be taken into account. Fig. 1 shows the curves of available enthalpy of air at an absolute pressure of 1 atm and at ambient temperatures t_0 of 0°, 15°, and 30°C, based on the tables of total heat and entropy published by Schmidt[11] and calculated by means of eq. (2).

When the chemical composition of the combustion gases is known, their available enthalpy can be calculated by means of eq. (2) applied to each of the constituents. Each result is then multiplied by a fractional value f representing the proportion of the constituent per unit mass of combustion gases, and the sum gives the available enthalpy as

$$e = \Sigma f[i_1 - i_0 - T_0(s_1 - s_0)] \qquad (7)$$

Each of the constituents is at its own partial pressure, and this makes the calculation somewhat tedious. If, however, combustion occurs at ambient pressure p_0, as in a steam power plant, then, neglecting draught losses, the evaluations can be simplified considerably. Instead of eq. (7), it is possible to calculate the available enthalpy of these combustion gases at ambient pressure p_0 as

$$e = i_1 - i_0 - T_0 \int \frac{\mathrm{d}i}{T} \qquad (8)$$

where the integral is taken between the lower limit T_0 and the upper limit T_1. Its value is obtained by determining with a planimeter the area under the corresponding section of the $1/T$ curve in a diagram of reciprocal temperatures $1/T$ against total heat i, related values of i and T being taken from an i-t diagram. With the e-values thus obtained, an e-t diagram can be plotted, from which it is possible to read the available enthalpy for any temperature and any position in the steam-generating plant.

In most cases the requirements as regards accuracy are not so great as to make necessary the construction of a special i-t diagram for the fuel considered. From statistical data and theoretical considerations, a general i-t diagram has been produced[12] for all gases occurring in the combustion of natural fuels in air. This diagram relates temperatures to total heat for a standard cubic metre (i.e., at 0°C and 760 mm Hg) of combustion gas, with curves for zero excess air and for air only, as well as intermediate curves for excess-air values of 20, 40, 60, and 80% by volume. The diagram is claimed to give results with a maximum error of ±2·5%.

This diagram is used in conjunction with a number of auxiliary diagrams which serve to determine the quantity of the combustion gases, and their total heat and air content, per unit weight or volume of fuel at 0°C and 1 atm absolute pressure. There are curves, for example, which give the percentage volume v_{air} of the air content in the combustion gases, plotted against the lower calorific

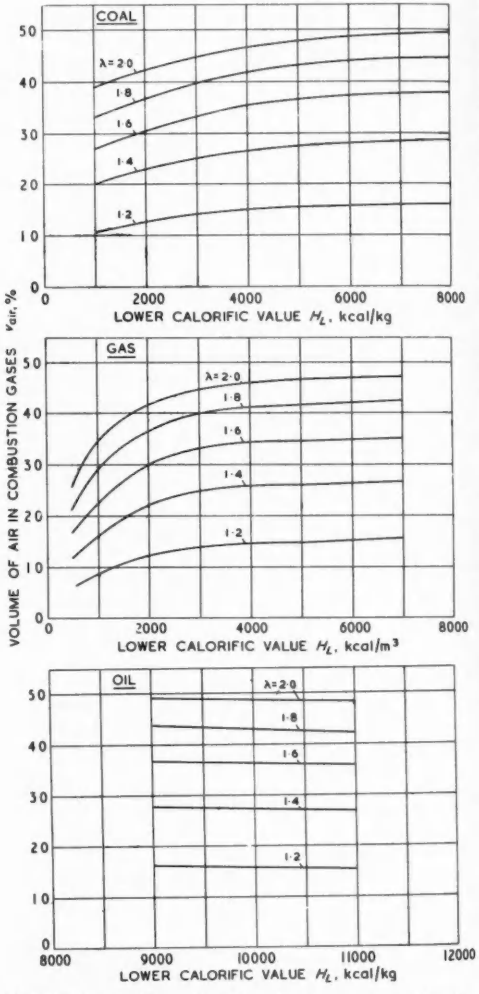

Fig. 2. Volume of air content in combustion gases as a function of the lower calorific values of a solid, gaseous, and liquid fuel, for different air/fuel ratios λ.

value, for air/fuel ratios λ from 1·2 to 2·0, as given in Fig. 2, which shows the results obtained with a solid, gaseous, and a liquid fuel. For flue gases, simple formulae are used to determine the total heat. A brief but clear introduction to the use of i-t diagrams has been given by Schmidt[11].

Generalized Available-Enthalpy Diagram for Combustion Gases

By means of eq. (8), a generalized available-enthalpy diagram for combustion gases can be constructed from the i-t diagram, and is valid for all gases generated by combustion of natural fuels in air at 1 atm. abs.

These generalized results become particularly simple to use if available enthalpy e is regarded as a function of the total heat i. Some approximate values thus obtained are reproduced in Table 1.

TABLE I: AVAILABLE ENTHALPY OF COMBUSTION GASES AT 0°C AMBIENT TEMPERATURE AND 1 ATM ABSOLUTE PRESSURE

Total Heat [kcal/m³]	Available Enthalpy e [kcal/m³]		
	No air	60% air by volume	Air only
25	3·0	3·4	3·7
50	9·6	10·6	11·2
75	19·0	20·5	21·6
100	30·5	32·8	34·2
125	43·8	46·6	48·9
150	58	61	64
200	90	94	97
250	124	129	132
375	217	224	228
500	318	325	330
750	529	539	546
1000	749	760	—
1250	964	—	—

The results in Table I show that there is little difference between the values for pure combustion gas and those for air only, particularly in the higher range of values.

These numerical results lead to the supposition that available enthalpy can be approximated by a single curve of mean values between zero and 60% by volume of excess air, i.e., a mean curve of 30% excess air. This does not eliminate the air content completely from the calculations, particularly since it is included in the determination of total heat from the *i-t* diagram, but it reduces the number of curves required, without an appreciable effect on accuracy. It should be noted that there are hardly any technical combustion processes at atmospheric pressure which operate with an air/fuel ratio greater than 2:1. All of these are accounted for by taking the air content of the gases as 50% by volume, a maximum air content of 60% including gases up to air/fuel ratios λ of 2·5. Thus, a curve for a mean air content will be valid for all practical cases. The mean values for 30% excess volume give an accuracy of $\pm 2\%$ for all total heat values above about 125 kcal/m³.

In most cases, it is necessary to determine the available enthalpy from temperature values, instead of directly from the *e-t* diagram. This can be achieved by including a *t-i* diagram (i.e., a generalized *i-t* diagram with its *i*-values as abscissae) in the plot of the *e-t* diagram, as shown in Fig. 3). For a given temperature T_1 and a given air volume v_1 of the gases, first the total heat i_1 is determined (following the broken line t_1-*N*-*A*-i_1). The intersection *A* of the *i*-curve with the available-enthalpy curve gives the corresponding available enthalpy e_1'.

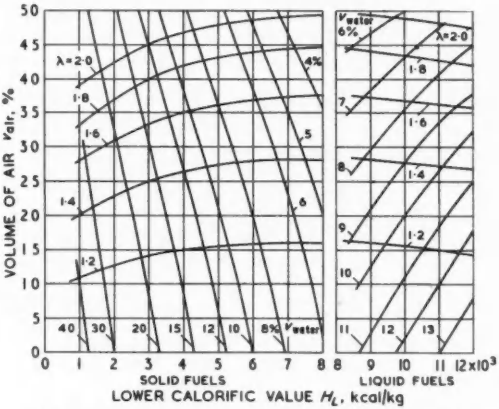

Fig. 4. Percentage volume of water vapour of the combustion gases from solid and liquid fuels as a function of their lower calorific value, air/fuel ratio, or air content.

Now, this value of e_1' requires a correction because, in the generalized *t-i* diagram, the water vapour included in the combustion gases is regarded as a permanent gas which does not condense at 0°C. Although this is unimportant for total-heat calculations of fuels, using lower calorific values, it should be borne in mind that e_1' still contains the "cooling-down" contribution of the water vapour. The available enthalpy of condensation e'' is constant above the dew-point and depends only on the quantity of water vapour contained in the gases. The value of e_1' has to be increased by this amount, which can be determined from

$$e'' = m[i_d - i_0 - T_0(s_d - s_0)] \qquad .. \qquad (9)$$

where m is the proportion of water vapour in the gases, and i_d and s_d are respectively the values of total heat and entropy at the dew-point.

The correction for available enthalpy of condensation is provided by the parallel lines *c* at the bottom of the diagram in Fig. 3. For solid and liquid fuels, the water-vapour content (percentage volume) can be related to the lower calorific value H_L and the air/fuel ratio λ or the air content v_{air} on the basis of statistical data based on fuel analyses[12]. The percentage volume can be readily determined by means of the curves in Fig. 4. After this value has been found, the line *NA* in Fig. 3 is extended downwards to the point *B*. Then $e_1 = AB$ is the available enthalpy of the gases at the temperature t_1.

A further correction is required to take account of the fact that combustion is not fully adiabatic, but is associated with heat losses, so that the theoretical tem-

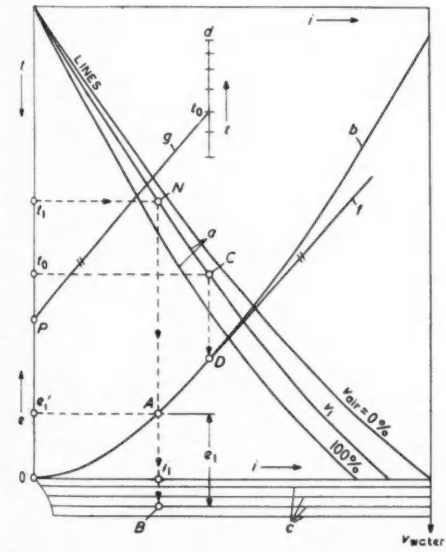

Fig. 3. Generalized structure of a *t-e-i* diagram for combustion gases.

(a) *t-i* lines for various air contents in the combustion gases.
(b) Available-enthalpy line for a definite ambient temperature.
(c) Parallel lines for the correction of available enthalpy for condensation of water vapour in the combustion gases.
(d) Temperature scale for determining the direction of the tangent to the available-enthalpy line (*b*).
(f) Tangent to the available-enthalpy line (*b*) through the point *D*, parallel to line (*g*), which leads from the temperature scale (*d*) to the pole *P*.

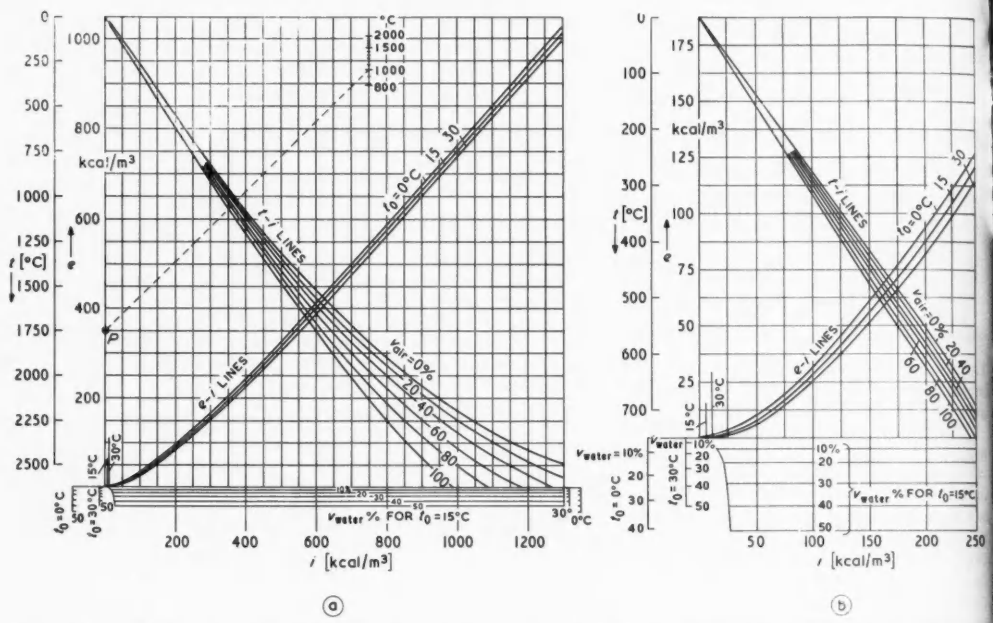

Fig. 6. Generalized *e-i-t* diagrams for combustion gases, for temperatures (a) between 0 and 2500°C, and (b) between 0 and 750°C.

perature is not reached. It can be assumed for simplicity that, during combustion, the temperature remains substantially constant, a reasonable assumption in practice. The *t-i* diagram now deviates from the theoretical diagram by having a temperature curve with a constant section corresponding to the maximum temperature. The total heat supplied and hence also released during combustion remains unchanged during this condition. Fig. 5 shows the corresponding diagram, with a *t-i* line going from the origin to points *D*, *A*, and *C*. The total heat supplied is i_0, which corresponds to a maximum (theoretically adiabatic) gas temperature t_A. The cooling down of the gases along the *a*-line occurs only after combustion. This theoretical *t-i* line corresponds to the *e*-curve in the available-enthalpy diagram. In reality, however, only the temperature t_D is reached, combustion taking place with a dissipation of heat to the outside at this constant temperature and beginning at point *B* with the initial total heat i_0. Combustion is completed at point *D*, and the gases cool down further along the theoretical *t-i* line. The angular transition at point *D* is, of course, an approximation.

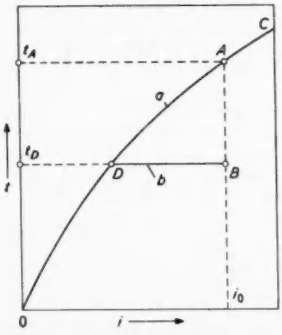

Fig. 5. Simplified *t-i* diagram of combustion gases.
(*a*) Theoretical *t-i* line corresponding to adiabatic combustion.
(*b*) *t-i* line for combustion at constant temperature.

The increase in available enthalpy of the gases between points *D* and *B* is equal to the available enthalpy of the heat obtainable through isothermal change from *D* to *B*; this heat is $q_{DB} = i_0 - i_D$, so that the additional available enthalpy is

$$e_{DB} = (i_0 - i_D)(T_D - T_0)/T_D \quad .. \quad .. \quad (10)$$

This is a straight line, which is a tangent to the available-enthalpy curve at point *D* in Fig. 3, and replaces the theoretical available-enthalpy curve beyond this point *D*. The line *d* and the pole *P* in Fig. 3 enable the tangent to be constructed accurately. Although this temperature scale is, strictly speaking, valid for 15°C ambient temperature, it can also be used for ambient temperatures between 0°C and 15°C without appreciable error.

Generalized available-enthalpy, total-heat, and temperature diagrams for two ranges of temperatures are presented in Figs. 6a and 6b.

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INTERNATIONAL MACHINE TOOL EXHIBITION 1960

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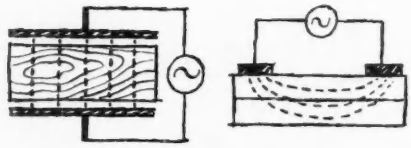
Dielectric Heating - 1

When an electrically non-conducting material is placed between two metal plates, called electrodes, connected to an A.C. supply, the alternating electrostatic field between the electrodes considerably speeds up the molecular movements in the material (termed a 'dielectric') as a result of which the temperature of the material under treatment rises. A similar effect is produced where the two



electrodes are positioned on the same side of the dielectric; in this case the electrostatic field between them is generally known as a 'stray' or 'fringe' field. For industrial application, the applied voltage of the order of 15,000 volts supplied by an electronic generator alternates at frequencies of some millions of cycles per second.

The amount of heat generated in the dielectric is determined by the frequency, the square of the applied voltage, the dimensions of the object and a physical property of the material termed 'loss factor' and is represented by the equation:

$$\text{Power} = 1.41\ E^2\ f.F.\ \frac{A}{t} \times 10^{-15}\ \text{kW}.$$

Where E = applied voltage, f = frequency, F = loss factor.

A = area of the dielectric in square inches.

t = thickness of the dielectric in inches.

F, the loss factor, is itself equal to the expression K Cos Ø in which:
K = the dielectric constant of the material,

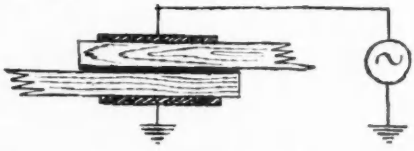
Cos Ø = the dielectric power factor of the material.

Therefore, 'loss factor' is a property of the material and a measure of the ease with which it can be heated by this method. Like other physical properties, it varies considerably for different substances. The equation shows that the heat generated in a dielectric is proportional to its loss factor, but the rate of rise of temperature will also depend upon its specific heat and density. The following table gives approximate values of the dielectric constant, power factor and loss factor of a few typical dielectric materials for frequencies around a million cycles a second.

MATERIAL	DIELECTRIC CONSTANT	POWER FACTOR	LOSS FACTOR
Natural Rubber	2·9	0·02	0·058
Oak, dry	3·3	0·04	0·132
P.V.C.	5·3	0·06	0·318
Nylon	3·7	0·05	0·185
Water, pure	80·0	0·03	2·40
Water, tap	80·0	0·5/5·0	40/400

The high loss factor of water means that materials which are difficult to heat when completely dry will often heat efficiently when moisture is present. The voltage must be increased towards the end of the process in some cases to remove the final moisture traces, the reduction in loss factor as the material dries out providing a safeguard against overheating.

If the workpiece is made up of a number of materials, each material will heat up uniformly but each at a rate depending upon its loss factor, thermal properties and density. The degree of temperature uniformity throughout the workpiece will then depend upon the extent to which thermal conductivity can equalise different rates of heating.



Such different rates of heating can be turned to good account in certain applications. For example, in wood glue setting, the glue lines heat up much more rapidly than the wood pieces being joined and the glue sets before the wood heats up substantially, wood having a lower loss factor than glue.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Tel: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available—"Induction and Dielectric Heating" is an example.

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British Industrial Developments

Automatic Hardening and Tempering Installation for Carbine-Barrel Forgings

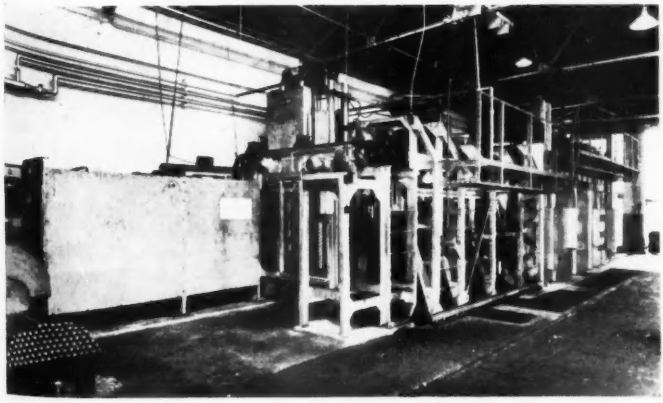
Designed and constructed by G.W.B. Furnaces Limited, of Dudley, Worcs., a fully automatic continuous hardening and tempering installation for the treatment of carbine-barrel forgings has recently been installed at the Royal Ordnance Factory, Fazakerley, Liverpool. In this connection, it should be noted that rifle-barrel forgings were previously treated in gas-fired batch furnaces, served by a single traversing charging machine, and hardening, tempering, and quenching were separate operations, each requiring the use of the charging machine. Also, the forgings were loaded horizontally, naturally leading to an appreciable percentage having some measure of distortion during heat treatment. With the new installation, this has now been substantially reduced.

The new G.W.B. furnace installation is almost completely automatic in operation, requiring only one operator to supervise control, loading, and unloading. The different sections of the furnace are linked by conveyors, and the separate operations are carried out automatically, so that high productivity is obtained and supervision is reduced to a minimum. Refinements in the actual heat treatment and the use of special suspension jigs for the forgings produce a much better finish and effect a considerable reduction in the quantity of rejected material. The unit is adaptable in that, if required, the hardening and tempering sections of the furnace can be worked separately and the various sequences can be adapted to suit changing requirements.

The complete installation comprises one pusher-type hardening furnace with an automatic quench and a degreasing unit, together with a pusher-type tempering furnace, also equipped with quenching and degreasing plant. Both quench units are equipped with oil-circulating pumps and oil coolers, and a protective atmosphere plant is employed for use with the hardening furnace. These items of equipment are arranged in the form of a "U", the hardening furnace and its quench tank and degreaser forming the first leg, the bottom of the "U" being formed by an electrically driven cross-traversing track, and the other leg by the tempering furnace and quenching and degreasing units. A further cross-traversing conveyor links the end of the tempering line with the entry to the hardening furnace.

Barrels are suspended from specially constructed heat-resisting jigs, each capable of carrying eight forgings, loading and unloading being effected whilst the carriers are on the final cross-traversing track conveyor. The loading sequence is approximately 7½ min. Forgings to be treated are conveyed automatically under the pivoted head of the hardening-furnace hydraulic pusher, which is of overhead-mounted design and which conveys the carriers separately into the hardening furnace. A rating of 120 kW is included in two independent automatically controlled zones, giving a maximum temperature of 900°C. Normal operating temperature is 850°C with soaking times of 1 to 1½ hr. Robustly constructed with a gas-tight casing, the furnace is well insulated to minimize body losses. Two rows of heat-resisting skid rails support the charge carriers during their passage through the furnace. Heavy-section nickel-chromium strip-heating elements are arranged on the side walls of the chamber, supported by a special hook-suspension method. At each end of the furnace is an electrically operated, fully insulated counterbalanced door. Fitted to the base of the entrance door is a unit section of skid rails used for alignment purposes during charging operations.

A gas-lock chamber is situated at the entrance of the hardening furnace, whilst at the exit is fitted a gas-tight quenching hood, the bottom edges of which are immersed below the level of the quenching medium. In addition to preserving the protective atmosphere, the quenching hood also ensures that the charge ready for immersion is completely free from the cooling effect of draughts, and tends to produce a constant and uniform quenching temperature. As the pusher propels the carriers through the furnace, an extractor gear is timed to remove the carrier from the furnace chamber to the platform of a quenching hoist. This extractor gear comprises a steel frame sited immediately above the quench tank, and the extractor head is provided with a pivoted pawl. Immediately the extractor gear has removed the charge carrier from the furnace and has deposited it on the quench hoist platform, the platform automatically lowers and places the carrier onto the quench conveyor, which conveys the charge through the quenching medium and also through the degreasing unit. In the gas-heated degreasing unit, the barrels are sprayed from a battery of fixed jets which are supplied with degreasing solution from a motorized pumping unit. In the base of the degreaser is a gas-heated



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coil which controls the temperature of the solution by means of a dialthermometer.

A further extractor gear, similar in construction to that previously mentioned, removes the charge carriers from the quench conveyor and transfers them onto a traversing conveyor, which takes them into the tempering-furnace line, where they are pushed into the tempering furnace by a second pusher gear. With a rating of 90 kW in three independent automatically controlled zones, this unit has a maximum temperature of 650°C. Generally, the tempering furnace is similar in construction to the hardening unit but, since no protective atmosphere is employed, the fittings connected with this process are not present. Different types of forgings are soaked for periods ranging from 1½ to 3 hr at temperatures up to 650°C, and, as these treatments are in the lower temperature ranges, some form of air circulation is necessary to provide efficient distribution of the heat. For this purpose, four air-circulating fans are located in the furnace roof, and baffles of heat-resisting alloy are specially situated to give directional air flow over the heating elements and through the working space. Quenching and degreasing arrangements, together with the extractor and conveyor systems, are similar to those in the hardening-furnace line, so that a continuous conveyor system is formed, linking all operations.

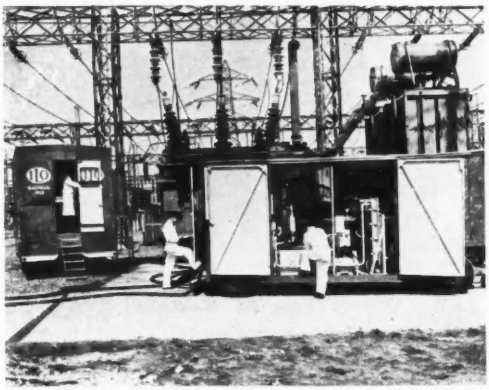
Each of the furnaces is provided with its own set of electrical equipment, all of G.W.B. manufacture. The switchgear comprises two iron-clad contactor cubicles, one for each furnace, and a totally enclosed motor panel housing 60 motor contactors for the various pusher, extractor, hoist, and conveyor drives. Automatic temperature control for both furnaces is provided by a common instrument control panel. A complete sequence of operations for the installation is carried out automatically, and all the necessary limit-switches and similar interlocks are controlled from a master sequence time-switch in the instrument control panel. The protective-atmosphere plant is a standard G.W.B. burnt town gas exothermic unit with a capacity of 1000 cu ft per hour and linked with a G.W.B. silica-gel gas drying plant.

Mobile Conditioning Plant for Transformers and Transformer Oil

Designed to be used on site for drying out "wet" transformers and for filling new transformers with de-aerated and super-dried oil, the new mobile conditioning-plant service announced by Wakefield-Dick Industrial Oils Ltd., of London, N.W.1, removes air, water, and solid contaminants from transformer oil, perfecting its physical condition and hence the solid insulation of transformer windings, ensuring the maximum degree of safety when the transformer is on load. Operation of the plant, which is designated the "Ilovac" unit, is controlled by a Wakefield-Dick chemist and his staff.

The "Ilovac" unit is mounted on a road trailer, constituting a mobile laboratory which is fully equipped for performing all the tests necessary to ascertain the condition of oil and to check on the efficient operation of the plant. Besides facilities for thorough inspection of oil samples for physical condition, oil can be tested for acidity, for free water content by crackle test and for dissolved water content by the Karl Fischer method. Equipment for determining the dissolved gas content of oil is carried, and the electrical quality of the oil is checked by apparatus which determines the electric strength and measures electrical resistivity. The laboratory also has equipment which can be used for measuring transformer insulation resistance. Special sampling devices are fitted to the unit for drawing off samples of oil, before and after treatment in the unit, under conditions of positive or negative pressure.

The equipment is designed for continuous treatment and, as it has its own high-capacity heating system, treatment is rapid and efficient. Thus, for example, during a typical servicing period, this equipment has reduced in a single pass the dissolved air content of oil from 11% by volume to 5% by volume, and dissolved moisture from 30 to 13 ppm. Simultaneously, the electric strength was raised from under 30 kV to over 75 kV. With continuous circulation, involving repeated passes of oil through the equipment, considerably lower figures for water and air content have been recorded.

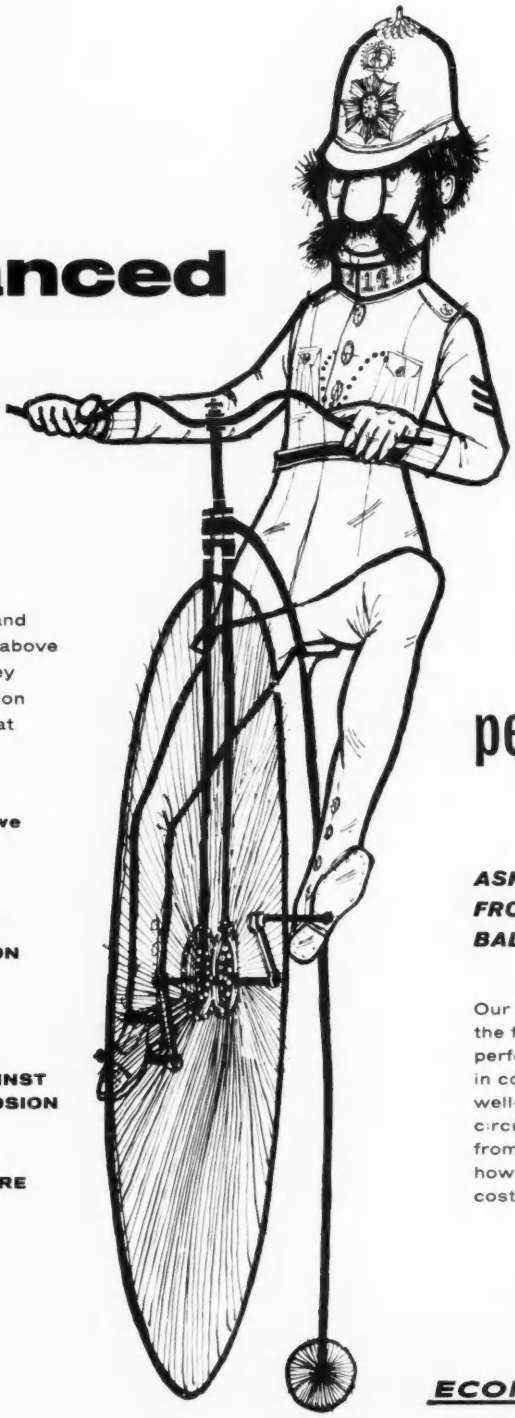


These results, which were obtained with a treatment rate of 1000 to 1200 gph, are due to a number of special features in the equipment. For example, the free water and solids are first separated out in the bowl of a high-vacuum De Laval centrifuge. The clean oil is then discharged through the centrifuge at a temperature above the boiling point of water at the vacuum used, ensuring very rapid removal of the dissolved water. The oil from the centrifuge is discharged into a vacuum holding and collecting tank and is recycled through spray nozzles into this tank before its final discharge. The atomization in this recycling system does not produce as fine a mist as that from the centrifuge bowl, but the device enables the oil to be held under vacuum for a longer period of time, helping to reduce still further the dissolved air and moisture content of the oil.

The equipment has ample heating capacity, embodying two 72-kW continuous flow type electric heaters. The elements of the heaters are sufficiently low in intensity per unit surface area to eliminate any possibility of damage to the oil because of local overheating. A De Laval plate-type heat exchanger, designed to give at least 50% heat recovery, makes it unnecessary to use the full heating power of the system continuously, except when drying of the windings needs the highest possible temperature throughout the treatment period.

The equipment includes vacuum pumps for the treatment plant itself and for coupling to the transformer to be filled. The main vacuum pump is an air-ballasted "dry-running" type which eliminates the possibility of condensation in the pump, and is capable of producing a vacuum of 0·01 mm Hg against a closed valve. The

Balanced



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transformer pump is of much higher displacement, but is not required to work at a correspondingly high vacuum. The vacuum tank is insulated to prevent heat loss in the oil and to use the available heating capacity at the most economic level. An automatic control system governs liquid levels throughout the equipment, as well as the oil flow through the recycling nozzles in the vacuum tank. Flowmeters are fitted, and there is an inspection and access window for the spray nozzles.

A separate circulating pump, with a capacity of 2000 gph, maintains the oil temperature during treatment of the transformer. This pump collects oil from the line from the transformer and passes it through one 72-kW heater bank and then back to the transformer. This operation is concurrent with the centrifugal and vacuum treatment of the oil, which is returned to the transformer at about 1000 gph, and ensures the maximum use being made of the heating capacity of the unit.

Automatic Sheet-Metal Grading Machine

The Bren Manufacturing Co., of Team Valley, Gateshead, a branch of the R. W. Crabtree organization, has produced a new automatic sheet-metal grading machine for an American company, the F. J. Littell Machine Co., who manufacture sheeting lines and other equipment for handling metal in coil form. Basically intended for use in a complete sheeting line of a coil-fed type for the canning industry, the Crabtree grading machine has several advantages over existing graders. Thus, although the graders at present used in these lines are automatic in selection, the supplying of pallets, positioning, disengaging, and unloading are all manual operations. On the other hand, the Crabtree grader is fully automatic, the only manual handling required being the removal of loaded pallets. Furthermore, it is from 12 to 14 ft less in length than existing graders available in the U.S.A. and has a much better appearance.

The Crabtree grader is a two-station machine which, acting on signals, automatically separates prime and reject sheets and stacks them neatly on pallets. This particular machine is capable of handling sheets from 18 × 24 in. to 38 × 44 in. at a maximum rate of 175 sheets per minute and can carry pallet loads up to 9000 lb. The normal operating speed of the conveyor belts is about 700 fpm, but, through a P.I.V. gear, is infinitely variable from 100 to 1200 fpm. Pallet positioning, hoisting, lowering, and ejection in the prime-sheet stacker are fully automatic, the action being dependent on a preset determination of the number of sheets on a pallet. Fig. 1 is a rear view of the machine, showing in the foreground the empty-pallet loading arrangement, on the left the motorized section of the discharging section, and on the extreme right the undriven section. The control panel can be seen between the two starting stations.

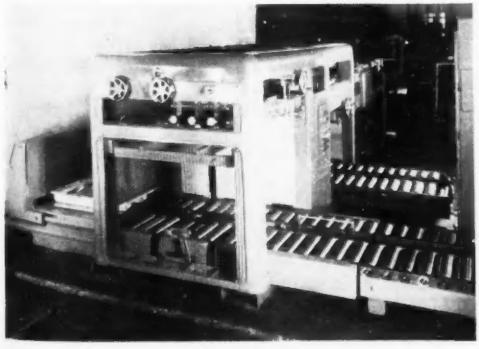

Fig. 1.

In operation, sheets are fed to the conveyor by a shear line which has cropped them from coil-strip. At an early stage of conveying, the reject gate is positioned, and reject loading is the first stacking station. Within a short distance of this position, there is a mechanism for throwing up single sheets for inspection.

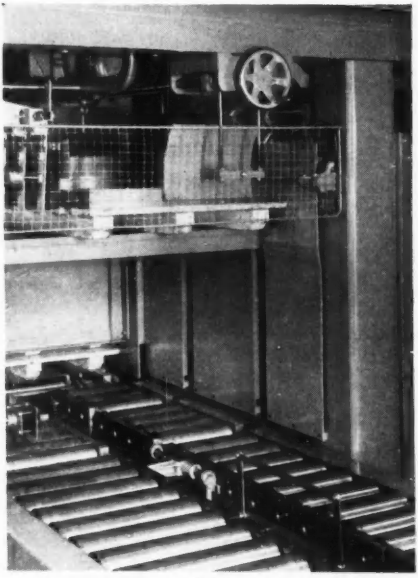

Fig. 2.

Prime sheets are carried along to the stacking position at the end of the machine and drop between the guides to fall in a natural stacked position on a pallet. A general view of the prime-sheet stacking station with a pallet in position, is shown in Fig. 2. When the preset number of sheets has been passed into the stacker, a trip is electrically operated and starts the automatic unloading cycle. Four prongs, moving through the stacker until they are supported by extension bars fitted to the rear of the grader. shoot out from the pile plate and catch the first sheet of the next pile. The full pallet is lowered until it rests upon the rollers on the floor. The rollers then move the full pallet towards the left and, at the same time, an empty pallet is forwarded onto the revolving rollers. This empty pallet is correctly positioned above the pile beams by retractable stops. When the full pallet is clear of the stacker, the rollers and chain dogs stop, and the pile beam assembly rises, bringing with it the new empty pallet. The hoist is stopped when the empty pallet supports the sheets and the prongs are removed from the slots in the top of the pallet. The top sheet is then again kept at a constant height until the next preset number of sheets has been counted, and the operation is repeated.

When a full pallet has rolled to the end of the ejection conveyor, it sets off an alarm bell which ceases to ring only when the pallet has been removed. Similarly, a bell

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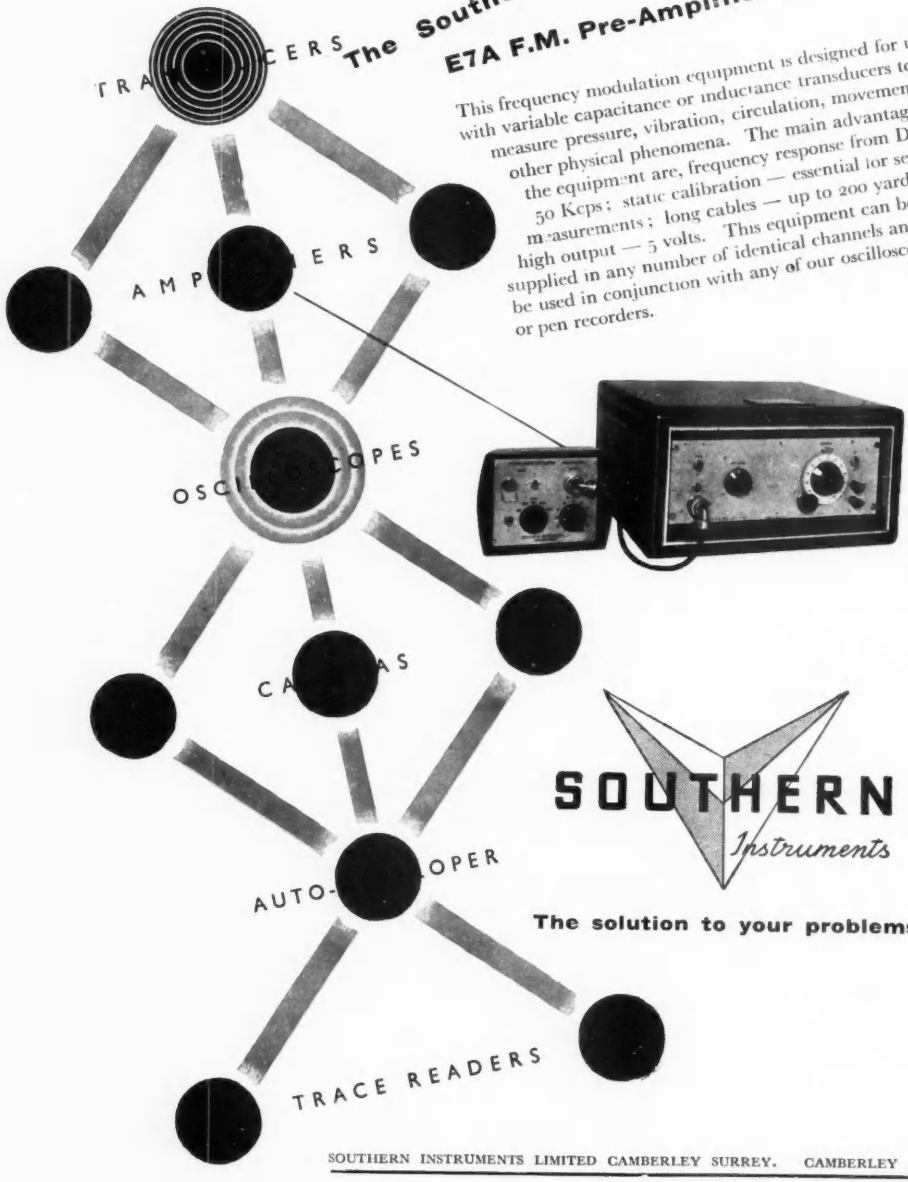

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gives warning when the last of the empty pallets has been used from the incoming hopper. These audible warnings are supported by different coloured lights which show on the control panel.

The control panel is linked with the shear line, and rejection of sheets is governed by an electronic memory device which passes signals based upon a thickness tolerance of $\pm 0{\cdot}0005$ in., the detection of perforations, and the surface condition of the sheeting. This signal electrically operates the rejection gate on the grader, the appropriate sheet being diverted to the lower conveyor which leads to the reject stacking station. Photo-electric cells control the height of the prime and reject stacks and start the sequence of electro-mechanical processes which eject full pallets and replace them with empty pallets. Additional push-button arrangements have been made, however, for manual operation of the pallet hoist, if required at any time.

From the point of view of safety, a pile-up of sheets along the conveyors will automatically shut down the complete line; in addition, manually operated emergency shut-down buttons, strategically situated around the machine, are provided. A limit-switch also closes down the machinery should, for any reason, the pile beams rise beyond the preset height. Handwheels on the sides and rear of the grader provide adjustment for various widths and lengths of sheets. By this means, the side guides are moved in simultaneously to ensure that the sheet remains centrally located with the pile beams.

Although the first Crabtree grading machine will, as already mentioned, probably be supplied in a sheeting line for the canning industry, the manufacturers envisage much wider applications, including electrolytic tinning lines in the steel industry and in production processes involving aluminium sheeting. In fact, aluminium sheets have already been run through on the grader with marked success, no end or surface damage having been experienced.

Automatic Transfer Presses for Cold-Forming

As announced by the sole selling agents in the U.K., the Rockwell Machine Tool Co. Ltd., of London, N.W.2, the range of "Boltmaster" machines manufactured by Maschinenfabrik Peltzer & Ehlers, of Krefeld, Germany, are fully automatic four-stage transfer presses for all types of cold-forming operations. Using both cold-forming and extrusion processes, these machines have been designed to produce from wire or bar stock many components which are at present generally turned on automatics. It is stated that considerable material savings are effected by using these processes, and the parts produced are of comparable quality.

Four sizes of "Boltmaster" machines are manufactured, the largest of which will produce components up to 10 in. in length using the cold-heading process, or up to $6\frac{1}{2}$ in. in length using the extrusion process. The approximate nett weight of this model is 59 tons. The machine shown in Fig. 1 is the model GB-100 for components up to 5 in. long (cold-heading) or $2\frac{3}{4}$ in. long (extrusion). Maximum stock diameter is $\frac{5}{8}$ in., feed length is adjustable from $\frac{3}{8}$ to 6 in., and the operating speed is 70 to 90 strokes per minute.

The stock is fed to the cut-off station through a two-way straightener by power-driven feed rolls. The cut-off blade is fitted directly to the main slide, cutting taking

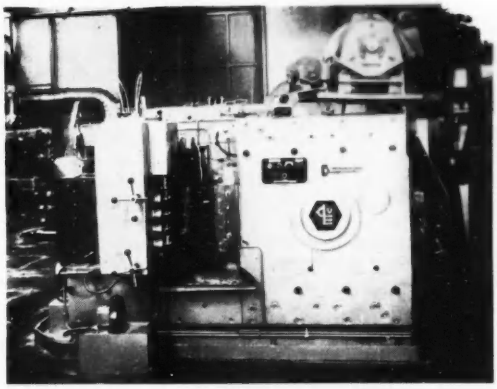

Fig. 1.

place at the end of the main-slide stroke. The blade places the cut-off length into a swivelling fixture which turns the blank through 90 deg. into the pressing direction and then passes it to the holding device of the first transfer arm. This arm remains in front of the first die station until the blank is inserted in the die by the advancing movement of the main slide. After the pressing operation has been completed, a cam-actuated die-ejector pin slides the blank out and into the second transfer arm, this process repeating itself up to the last die station. Any

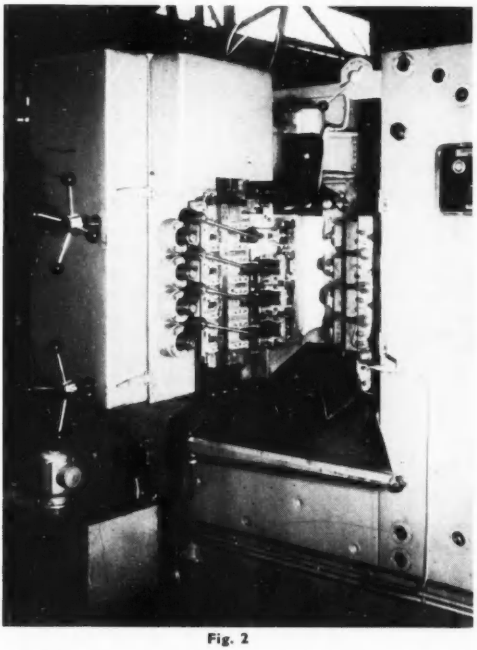

Fig. 2

trimming is effected at the last die station, employing a method by which the scrap is positively held. The finished parts and the trimmings leave the machine via separate chutes. The tools and dies are easily accessible and can be quickly changed. Furthermore, all operations of the tool unit are visible to the operator.

The four transfer arms (Fig. 2), which are fitted to a

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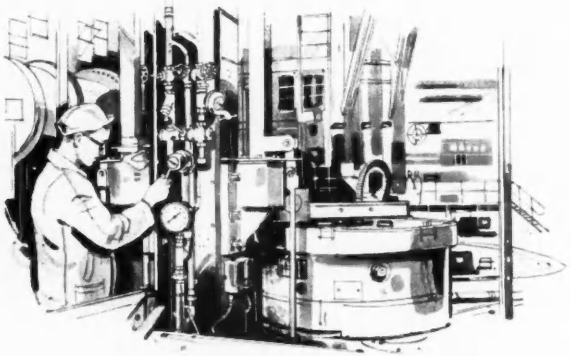

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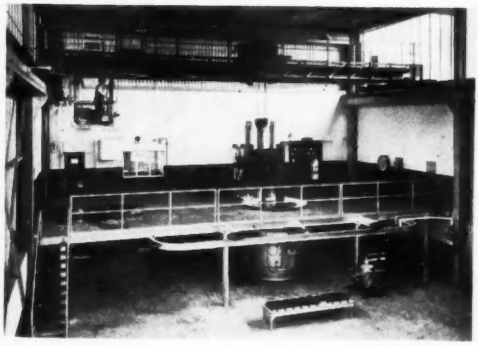
common carrier plate but are individually adjustable, are located by stops when transferring from one station to the next, their spring-loaded mountings making adjustment less critical. Should one of the pressings not be ejected from its die, thus preventing the appropriate transfer arm reaching its end position, a limit-switch is actuated and stops the machine through a friction clutch. The main-slide arms run in long guideways, permitting accurate alignment of the tools, which are mounted in a common adjustable block. These tools are provided with pressure adjustment, and the two inner heading stations have built-in power-operated ejection, the drive for which is derived from the connecting-rod motion.

Pilot Smelting-Furnace Service

Intended to promote the development of electric smelting processes, a contract service, available for the first time in the U.K., is available for electric smelting and is now in operation at the Aldridge premises of Birlec-Efco (Melting) Limited. This service makes it possible to accept customers' raw materials in trial batches for testing their amenity to electro-thermal reduction and for determining the most suitable smelting technique and the nature of the resulting products, using a pilot smelting furnace, which provides full-scale testing facilities for a fee agreed in advance. The finished products and the balance of materials are then returned to customers.



The plant is of such a size that valuable information can be gained on such important factors as power and electrode consumption, operating voltage, percentage recovery, and other relevant data. This information can be scaled up, so that a fairly accurate appraisal can be made of what can be expected on a large-scale plant. At the end of the test, a full report is presented, giving recommendations on smelting practice, electrical ratings, and the size of installation required for a given output. The furnace is capable of smelting calcium carbide, iron ores, manganese ores, nickel and copper concentrates, and can also be used for the production of ferro-silicon and ferro-chrome and for the treatment of slags, as well as for many other electro-thermal processes. In addition, the installation has laboratory facilities and a competent staff to carry out the development work for which it is intended.

The specially designed building housing the pilot smelting furnace has a total floor area of 5700 sq ft and is served by a 5-ton overhead travelling crane, the maximum height of lift being 26 ft. The substation, which is integral with the main building, is in an area adjoining the furnace and includes a 350-kVA three-phase transformer, a high-voltage contactor, a 0·7-kW amplidyne electrode controller, and a low-tension distribution board. In addition, ample provision is made in the building for the storage of refractories, electrodes, and raw materials, and equipment for crushing, ladle heating, and casting has been installed.

The pilot smelting furnace, with a shell of 8 ft i.d., is surrounded by a charging platform at a height of 9 ft above the main floor level, the furnace controls being suitably housed in a panel adjacent to the furnace operating platform. A general view of the pilot smelting plant, showing the furnace operating platform, is shown in the illustration.

Designed to be as versatile as possible, the furnace, which has a nominal rating of 350 kVA, is provided with a wide range of voltage tappings, enabling all electric smelting operations to be covered as far as is practicable. To determine the effect of shell rotation for different smelting operations, the shell can be rotated or oscillated in either direction at varying speeds. Three tapholes are provided, the levels of which can be altered for slag and metal, and are served by a mono-rail beneath the platform, forming a loop surrounding the shell. The mono-rail carries slag pots or metal ladles. Several thermo-couples are built into the refractory lining to monitor the temperature of the hearth and side-walls at different points.

The furnace is equipped with holders suitable for electrodes, 8 in. in diameter, which can be amorphous carbon or graphite, according to the requirements of the tests. Smaller electrode holders can be fitted, if necessary. The electrode clamps are arranged for remote control by pneumatically operated cylinders.

Automatic Control System for Metal-Spraying Operations

Introduced by the Metallizing Equipment Company Ltd., of Chobham, Woking, the " Metco " Type-C control system is a fully automatic electronic control unit for heavy-duty or production metallizing. The unit is built on the module system to give maximum flexibility in the degree of control required and will operate with both wire and powder metallizing processes.

The basic unit consists of electrically controlled inlet-air, oxygen, and gas valves. Permanent connection is made to these valves from the main factory supply, and gauges are fitted to show the supply pressure. As soon as fuel gas is supplied to the control system, a ventilating fan at the bottom of the unit is started, and indication is given by a green light at the top of the panel. If, at this stage, there is no air pressure in the supply line, the operating controls are locked out of circuit and remain out of circuit until the air pressure reaches the normal operating level. If, during operation of the machine, the air supply or the flame should fail for any reason, the entire machine will automatically shut off. In all cases where a safety control shuts down the unit, it requires positive action by the operator to re-start the system. Remote control can be incorporated where control of two or more metallizing machines can be operated from a master control panel or some other remote point. The operating unit consists of control buttons, pilot lights, and the electrical circuits. The buttons, together with the appropriate pilot lights, operate the main-power, testing

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and adjusting, metallizing, and idle and stop circuits.

With the controls set, depressing the metallizing button starts the lighting and operating sequence, which is operated by a time relay that first opens the air, oxygen, and gas valves to purge the lines, the relay then partly closing the valves to allow sufficient gas and oxygen for lighting purposes and operating the automatic igniter. In the next operation, the relay opens the valves fully and finally starts the wire feeding. The machine is then metallizing. While operating, the speed of the wire feed is maintained exactly by the electronic control unit, the range of speed covered by this unit being adequate for all normal metal-spraying operations. For the idle condition, the appropriate button is pressed, stopping the wire from feeding and reducing the gas and oxygen flow to leave only a pilot flame alight on the metallizing gun. Depressing the metallizing button then returns the flame to normal and starts wire feed again. This control can be automatically indexed by the component when metallizing on a production basis. When the system is shut down at the end of a run, all gases and pressures can be drained by operating the controls normally used for initial adjustments.

Normally, the control cabinet is permanently fixed in the most suitable operating condition, but it can be fitted into a base mounted on castors to permit ready movement of the whole unit, or so that the cabinet may be moved where an obstruction would prevent servicing. For complete flexibility, units can be readily added to the basic assembly to meet special requirements for any given metallizing operation. Failure of electric power, compressed air, gas supply, wire feed, dust extraction, or the mechanical handling of the component can shut down the entire system and indicate the appropriate failure. In fact, every step in the entire sequence has been so designed to provide a thoroughly safe installation.

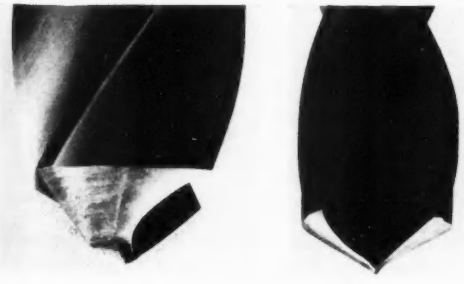
Spiral-Point Drill-Sharpening Machine

It is announced by Charles Churchill & Company Limited, of South Yardley, Birmingham, sole selling agents in the U.K. for Cincinnati machines, that a drill-sharpening machine which quickly and simply gives a drill a new form of point geometry, i.e., a spiral point, has been developed by the Cincinnati Lathe and Tool Co., of Cincinnati, Ohio. The sharpening machine, designated the " Spiropoint ", provides the complicated shape of the spiral point in a few seconds, and is a complete unit, with all electrical equipment, tools, grinding wheels, etc. included as standard equipment. The machine (Fig. 1) is mounted on casters and is equipped with screw-jacks for levelling on uneven floors. A dust collector, driven by a separate motor, is incorporated and is conveniently located in the machine base.

The spiral point developed by Cincinnati for standard twist-drills is stated to produce a precision tool which maintains accuracy in centre-punching, and enables holes to be made that are closer to size, rounder, straighter, and burr-free. In addition, drill life is increased, the drill thrust force required is reduced (often by as much as 34%), and there is less need for secondary operations such as reaming, while workpiece distortion is reduced because of the cooler cutting action and reduced thrust force.

Fig. 1.

The spiral-point drill has an actual point at its centre. On contacting the work, the drill automatically centres itself, without any tendency to " walk ". As a result, the spotting operation is eliminated and the need for jigs and fixtures is greatly reduced. Throughout the drilling operation the drill continues to centre itself, giving a clean, round, accurate, and straight hole. Also, the improved cutting angles at the point of the drill help to reduce heat generation in cutting, and the optimum clearance angles along the entire cutting edge enable the chips to flow more easily into the flute. For use in sheet-metal drilling, the self-centring action of the spiral-point drill has been found particularly helpful in obtaining truly round holes in thin soft metal and when the drill is held by hand. For sheet-metal applications, the spiral-point drill is given a point angle of 180 deg., as opposed to the usual 118 deg. Three close-up views of a spiral-point twist-drill are given in Fig. 2.



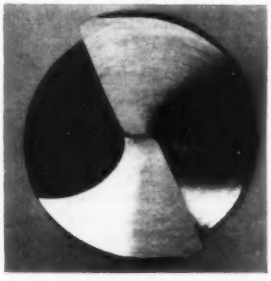
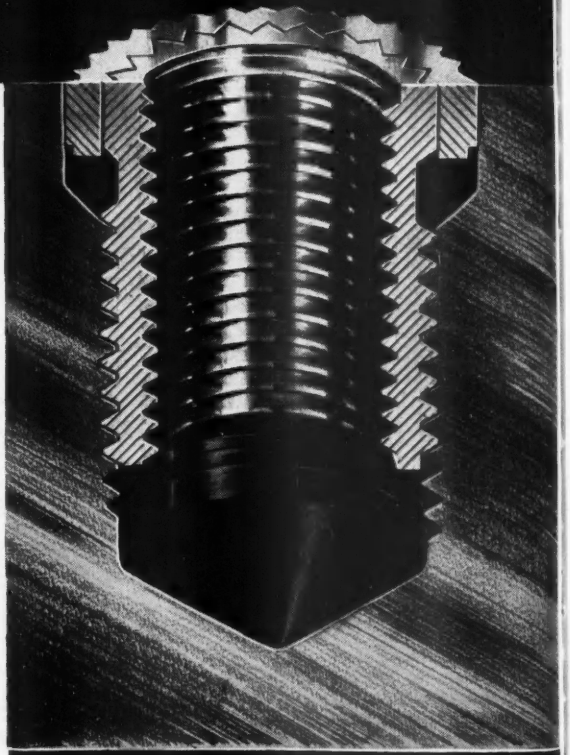


Fig. 2.

a tough thread in a soft metal



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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Self-Sustained Modulations in Transductor Circuits with Series Capacitators

By F. DAHLGREN and R. LADZINSKI
From *Transactions of the Royal Institute of Technology, Stockholm*, Sweden,
No. 148, 1959, 64 pages, 50 illustrations

TRANSDUCTORS with series capacitors in the a.c. circuits create, under certain conditions, amplitude modulations of all electrical quantities in the circuits involved. A contribution to the understanding of this phenomenon is presented in this paper, as well as a confirmation of experimental results, and is concerned with a theoretical and experimental investigation into the modulation phenomenon in transductors with capacitors in their a.c. circuits, with particular reference to parallel transductors of the type which are not self-excited.

By means of a procedure involving experimental measurements of certain fundamental relations, plotting of combined curves, and physical considerations, a clear explanation of the phenomena has been attained. This procedure is based on certain approximations with respect to the influence of harmonics, but experimental verifications, mainly by means of oscillograms, have, however, proved good agreement between actual results and conclusions from the theoretical reasoning. A purely mathematical method, employing Bessel functions, is briefly indicated.

It has also been shown that the results obtained are equally valid in the case of series transductors without self-excitation. Self-excited, and particularly auto-self-excited, transductors are, on the other hand, far less suitable for use in circuits where modulations are desired, and consequently more advantageous in cases where any tendency for creating modulations must be suppressed. In practical applications where for other reasons non-self-excited transductors have to be used in combination with series capacitors, the treatment in this paper furnishes a basis for dimensioning so as to obtain the desired qualities regarding self-sustained modulations, although the conditions are too complicated to permit the formulation of a simple and universal criterion for the appearance or non-appearance of such modulations.

Vibration Problems in Marine Engineering and their Solution

By W. MCLAUGHLIN
From a paper presented at a meeting of
The Institution of Engineers and Shipbuilders in Scotland,
February 26, 1960, 96 pages, 52 illustrations

IN this paper, a number of typical vibration problems in connection with vibration in turbo-geared and diesel machinery is discussed, and descriptions are given of electronic instruments for the location of the sources of vibration.

The problems described illustrate that no hard and fast rules can be laid down for the solution of a vibration problem, and that each must be treated on its own merits. The investigator must first try to establish the cause of the rogue noise or vibration and then correlate it with the speed of some component, search for some quality in the machinery, and establish which components of the machinery have that particular quality. Vibration search and analysis are very painstaking exercises, often necessitating the planning of analyses to suit trial programmes and the need to sit over an analyser, patiently awaiting changes of speed to obtain the data required. Preliminary planning of the search, preparation of correlation charts, and proper communication between the speed-measuring position and the analysing position shortens the time required for analyses.

The Corrosion Behaviour of High-Purity Vanadium

By D. SCHLAIN, C. B. KENAHAN, and W. L. ACHERMAN
From *Corrosion*, U.S.A.,
Vol. 16, No. 2, February 1960,
pp. 114–116, 2 illustrations

VANADIUM production has been undertaken by several companies now making the metal on a limited scale in a form pure enough to be ductile. Vanadium has the physical and mechanical properties desirable in a structural metal, but this metal and alloys based on it have not been applied to industrial uses because of high production costs and a lack of information on their properties. An extensive study of vanadium and some of its alloys is being made, and a study of the corrosion properties of these metals is part of the programme. This article gives the results of comparative studies of corrosion of ductile vanadium obtained from several sources.

Chemical and galvanic corrosion experiments have been carried out and show that vanadium is resistant to corrosion in substitute sea-water at 35°C. At this temperature, it is also resistant to corrosion in 60% sulphuric acid and 20% hydrochloric acid. It resists corrosion in 3% nitric acid, corrodes slowly in 12% nitric acid, and corrodes very rapidly in 17% nitric acid. The absence of air has little or no effect on the corrosion of vanadium in these environments. In substitute sea-water, vanadium is

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less noble than stainless steel and copper and more noble than aluminium, magnesium, or SAE 4130 steel. Coupled with these metals, vanadium behaves as a sacrificial metal for copper, but is protected by aluminium, SAE 4130 steel, and magnesium. Neither vanadium nor stainless steel is affected by contact with each other.

Vanadium from two sources exhibited essentially the same corrosion properties, although there was a considerable difference in iron content. Annealed and unannealed vanadium exhibited similar characteristics.

The Operation of Rolling-Element Bearings in a Protective Atmosphere

By A. G. CATTANEO, R. A. COIT, and S. S. SOREM
From an advance copy of a paper received from *The Institution of Mechanical Engineers, London,* March, 1960, 8 pages, 8 illustrations

INCREASING operating temperatures are a characteristic trend in the development of many modern machines. Sometimes, they are merely a consequence of progress in other directions, such as more compact design and higher operating speeds for lighter weight; at other times, the trend is deliberate, e.g., for improving the efficiency of a cycle or reducing the cooling requirement. In high-speed aircraft and missiles, and machinery associated with them, all these factors seem to reach a peak. In particular, air cooling, as a means of limiting the operating temperature, is no longer available when the stagnation temperature of the air itself equals or exceeds the desired limit, or the vehicle operates outside the atmosphere. Cooling with oil also ceases to be practical when the absorbed heat cannot be rejected to the surrounding air and the cooled oil recirculated. Total-loss systems can in some cases be used for lubrication but, to obtain a substantial cooling effect, impractically large quantities of the lubricant would have to be carried in a missile. Internal means of cooling, such as using the fuel as a heat sink, usually have to be reserved for the protection of special, sensitive equipment on board, such as electronic parts, instruments, or a pilot. As a result, machine parts that normally operate at 200 or 300°F, may now have to operate in an environment of temperatures of 500 to 1000°F, or even higher. Fortunately, in many such applications a relatively modest life, of 100 hr or less, is considered satisfactory, for the present at least.

To operate at temperatures up to 1100°F, bearings must be protected against two sources of early failure, i.e., the formation of red rust by oxygen attack on the surfaces in either rolling or sliding contact, and rapid wear by local seizure (scuffing) of the cage surfaces in sliding contact with other elements. The first function can be filled for all-ferrous bearings by an atmosphere consisting of a mixture of air and an organic vapour which acts as a reducing agent at elevated temperatures. The performance of the second function requires constituents or additives that form anti-scuffing films.

An olefine oxide polymer has been found to be a satisfactory reducing agent over the whole temperature range. Conventional extreme-pressure additives are effective in preventing scuffing up to about 900°F. Above 900°F, the polymer forms an organic film which itself gives some protection against scuffing. With the bearings available thus far, maximum loads are dictated by softening of the metals above 900°F. These high temperatures create special problems in the design of the test equipment with respect to fits, warping, and dimensional changes.

The work completed to date has demonstrated the feasibility of operating rolling-element bearings for extended periods under a protective atmosphere at temperatures substantially higher than those possible with currently available liquid lubricants and greases, and satisfactory bearing performance has been demonstrated for periods up to 100 hr at temperatures up to 1000°F and for 22 hr at 1100°F.

Trends in Transmission Design for Self-Propelled Diesel Railcars

By A. G. WILSON
From a paper presented at a meeting of *The Institution of Locomotive Engineers, London,* February 16, 1960, 21 pages, 4 illustrations

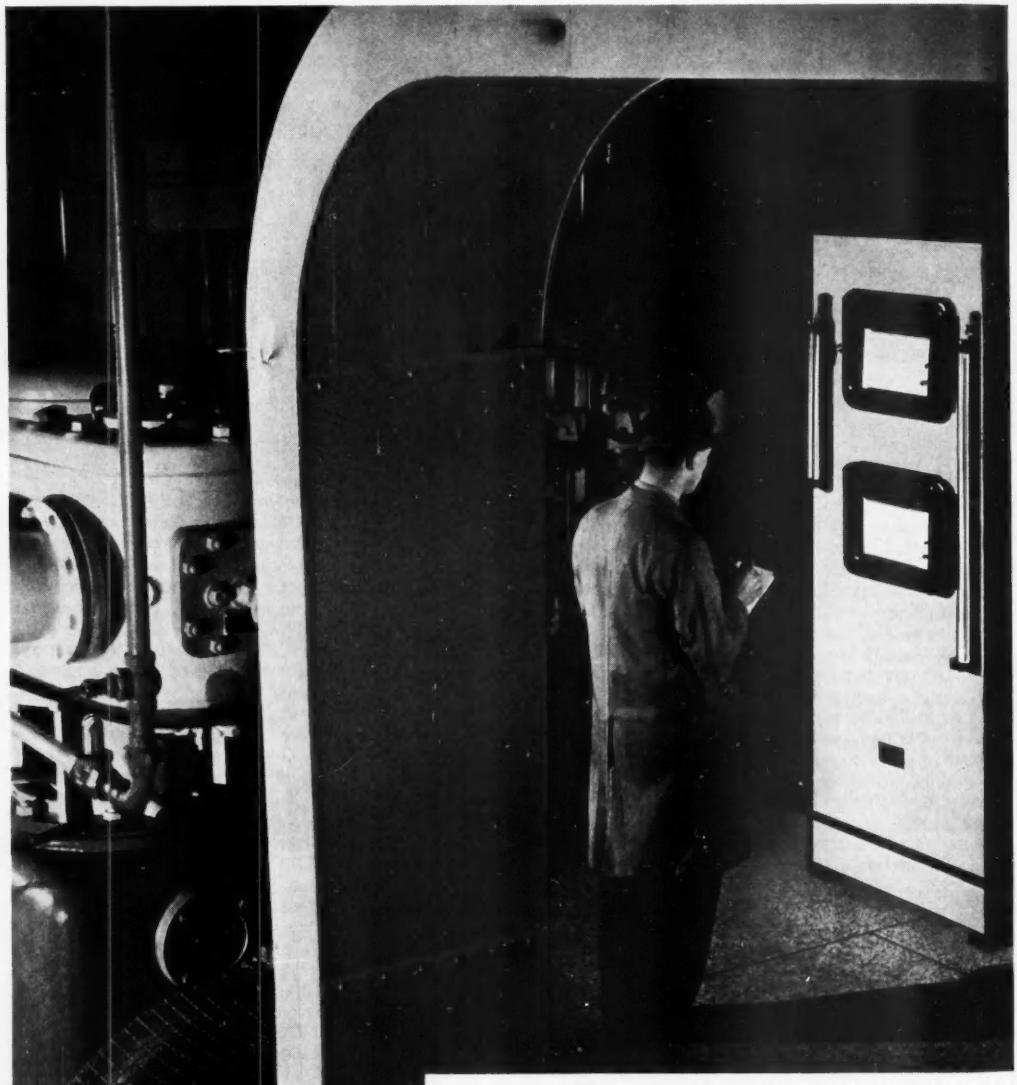
THE importance of diesel power in railway practice provides a justification for surveying certain aspects of design from time to time in order to gauge the trends, if possible to assess the reasons for them, and to forecast future developments. Since the self-propelled diesel railcar is now in use in such large numbers, and since it differs materially from the diesel locomotive in many respects, the field of this paper is limited to railcars and excludes locomotives. Its purpose is therefore to trace the effects of different transmission systems on railcar performance, and to deduce what features of these designs have commended themselves to users.

In looking to the future, it seems likely that developments influencing the transmission will be lighter diesel engines producing more power for their size than those at present available, and lighter construction of rolling stock. Technical developments standing out as urgent requirements are:—

(1) A torque converter with a power loss of not more than 5% or at most 10% over a torque range of 2 : 1, with a maximum torque-multiplcation ratio of 4 : 1.
(2) A simple automatic gearbox in which the changes of gear are accomplished automatically without the complication of electric or hydraulic devices.
(3) A simple method of providing bi-directional running while, positively preventing any of the power units being turned in the wrong direction.

These problems should be capable of solution and, when used either together or separately, should provide a transmission system for railcars which would greatly increase their usefulness. The trend, above all, would be towards reliability and simplicity. For the transmission to be simpler and more reliable, it should have less to do in the way of torque multiplication. Greater engine horse-power and lower car weight are the determining factors, since their relationship controls the degree of torque multiplication which must be provided.

Taken in the broadest sense, the self-propelled rail



The keen eye will be able to pick out in this photograph an Arkon Liquid Flow Indicator on the pipeline above, and Arkon Full Scale Pressure Gauges on the panel itself.

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unit potentially offers enormous advantages. It is extremely flexible from an operational standpoint in that trains of almost any size can be made up and split as desired, while the power/weight ratio remains constant. It offers the greatest possible pay load, since all the floor-space is available, and the extra weight on the vehicle is simply the power unit and its controls and fuel. It is not put out of action by the breakdown of any one power unit and it lends itself to unit replacement in the running shed.

Developments in technical improvements, both in engine and transmission, are a continuous process, and the aim should be to bring these along together, introducing them step by step. Much has been achieved in the last few years and progress has been stimulated by the success of the railcar as an important part of the Railways modernization scheme. Though many of the lessons that have been learned are only beginning to become appreciated, the next few years will undoubtedly show still more progress.

Torque Distribution, Power Flow, and Zero-Output Conditions of Epicyclic Gear Trains

By B. Jakobsson
From *Transactions of Chalmers University of Technology, Gothenburg*, Sweden
No. 224, 1960, 55 pp., 38 illustrations

Many machine designers still hesitate to use epicyclic gears, mainly because of the lack of understanding of how to analyse their behaviour. Thus, while they can deal with rotational speeds, they are often unable to cope with questions regarding the torque distribution on the different shafts concerned, as well as the influence of frictional and other losses. It is therefore the object of this paper to demonstrate and discuss thoroughly the basic principles of epicyclic gear-trains.

Essentially, this paper, in which only equilibrium problems are treated, demonstrates the behaviour of epicyclic gear-trains by a detailed treatment of an arbritrarily chosen example. The basis for analysis is an efficiency η_0 which is obtained when the planet carrier is at rest, and is normally considered as a constant value, e.g., 0·98 in practice. If further research should show that η_0 is not exactly the same in both power-flow directions, different values of η_0 have to be used, but the equations for torque distribution would still be valid. Moreover, the value of η_0 may show slight variations with lubrication, temperature, and other factors.

Irreversibility is characterized as zero-output power flow, which implies that all rotating shafts give input power to produce the power loss. This is discussed for three and four shafts. The losses considered are specified as tooth losses and planet-shaft bearing losses. Other losses might be included, but this would not change the results considerably. It is important to note that an irreversible gear train with three rotating shafts does not exist. As demonstrated, only under certain rotation conditions does zero-output power flow occur. When the sun-gear shafts rotate in the same direction, it cannot occur.

The Influence of Atmospheric Pressure and Temperature on the Performance of Naturally Aspirated Four-Stroke Compression-Ignition Engines

By C. B. Dicksee
From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*,
January 1960, 10 pages, 13 illustrations

It is unquestionably true that, in common with all other types of internal combustion engine, the compression-ignition engine is affected to some degree by changes in atmospheric condition. In the case of the petrol engine, where the fuel supply is governed by the air mass flow, any change in air flow, no matter how it arises, will automatically result in a change in fuel flow, and under these conditions a change in atmospheric density will have a more or less direct influence on the power developed.

The compression-ignition engine differs from the petrol engine in that the fuel supply is entirely independent of the air flow. Another, and almost more important difference, insofar as this paper is concerned, is that, even under full-load conditions, the engine operates with a large excess of air, the degree of air utilization ranging from about 50% in the large slow-speed engine to between 70 and 75% in the case of the automotive-type engine at its maximum output. Furthermore, at any one speed, the weight of air received at part load is the same as that received at full load, except for the small change in volumetric efficiency caused by a change in engine temperature. Under all conditions of operation there is therefore sufficient air present for the complete combustion of the fuel. From this it follows that a change in atmospheric condition, such as arises from the normal barometric and temperature variations in any given locality, does not affect the quantity of heat released within the combustion chamber. Clearly, then, any effect which such changes may produce cannot be anywhere near proportional to the change in the weight of air received into the engine, but must be on a much smaller scale and controlled from a different basis.

Unfortunately, this fundamental truth does not seem always to be realized, because it is by no means uncommon to find instances where a correction for atmospheric condition is applied to compression-ignition engine test-figures by the use of the formula devised for correcting petrol-engine test-figures. The experiments described in this paper are therefore designed to show the absurdity of this procedure and, if possible, to provide information from which a method of correcting compression-ignition engine results could be derived. The first objective is very definitely achieved; with regard to the second objective, it is shown that a change in air utilization has precisely the same effect on the indicated horsepower, no matter whether the change is caused by the fuel delivery being varied while the air supply remains the same, or whether the fuel supply is kept constant and the air supply varied by a temperature or pressure change.

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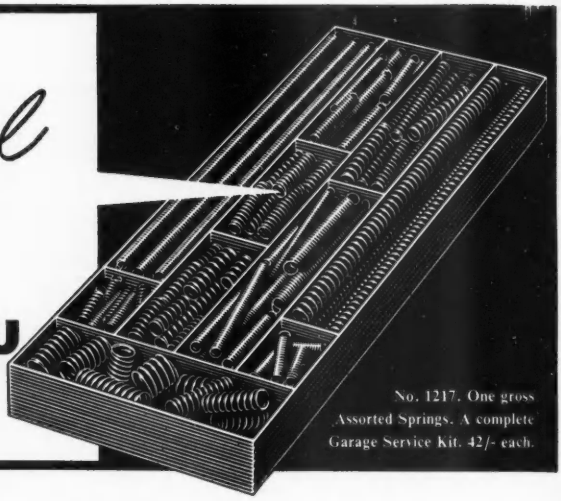

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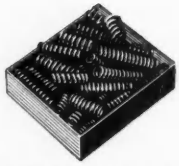

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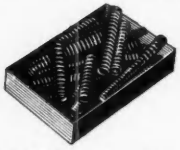

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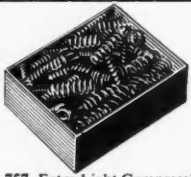

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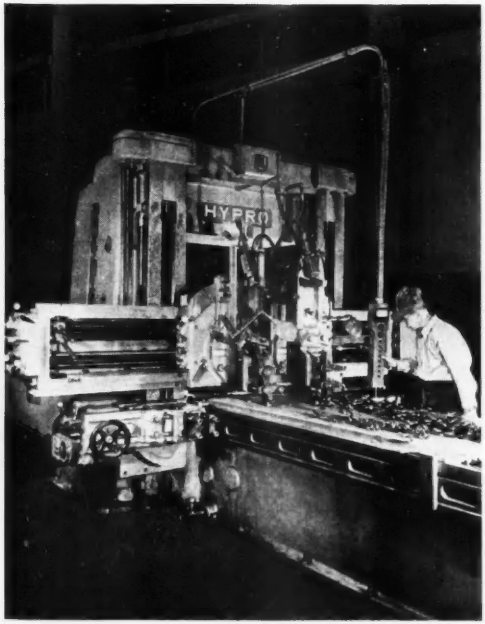
Large Double-Housing Planing Machine

With a bed length of 48 ft, a table length of 22 ft, and 49½ in. between the housings, the new "Hypro" extra-heavy double-housing planing machine recently developed by the Giddings & Lewis Machine Tool Co., Inc., of Fond du Lac, Wisconsin, is believed to be one of the largest machines of its kind ever constructed.

The machine, which weighs about 40 tons, is capable of precision operations on cast iron and steel at the high tool speed of 400 fpm, and incorporates a number of outstanding features, including dual saddle and slide controls, power cross-feed to the side heads, a twin helical-gear table drive, extra-high pneumatic tool-lifters for both rail and side heads, and hydraulic table stops and jacks. In addition, the machine utilizes large-diameter drive shafts, and anti-friction bearings on all screws, feed rods, and rapid-traverse shafts. A special high-power adjustable-voltage drive is fitted, giving a table-speed range between 25 and 400 fpm. The motor used incorporates low-inertia armatures and is designed for rapid reversals, as well as for rapid acceleration and deceleration.



All bearing surfaces of the bed and table ways, the gears, and the drive-shaft bearings are pressure-lubricated, oil being supplied by a motor-driven pump unit with a continuously operating, non-bypass full-flow filter. The oil pump is interlocked with the table-motor control circuit through a safety switch, so that the main drive motor will not run unless the oil pressure is adequate.

A limit-switch prevents the rail from being raised too far. Horizontal movement of the heads is limited by stops, and safety clutches protect the rail and all heads from running together or into workpieces. The feed and rapid-traverse mechanism cannot be engaged at the same time on any one head, while an interlock between the rail clamp and elevating mechanism prevents the rail from being raised or lowered when partially or fully clamped. A hydraulic table stop controls maximum table movement.

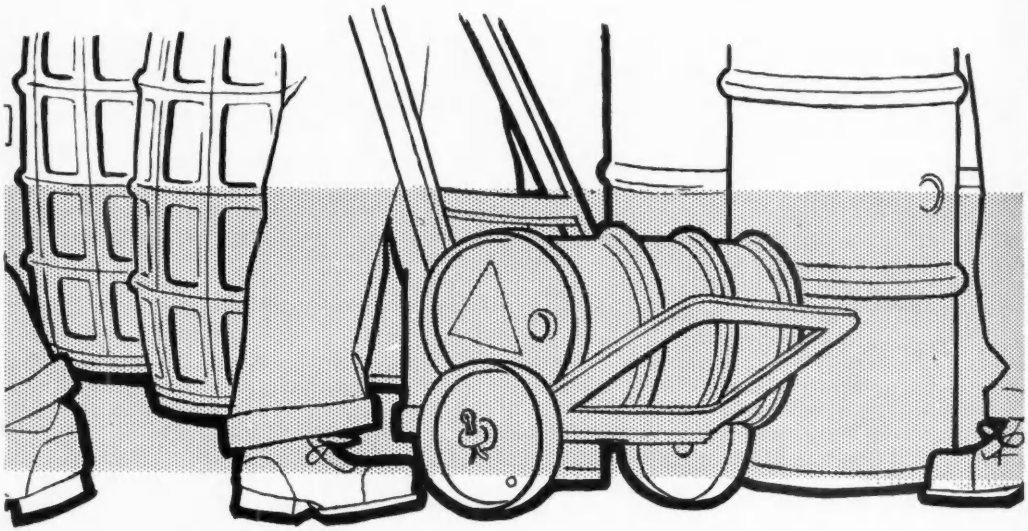
External Charging Device for Steam Accumulation

A method of increasing the efficiency of boilers in applications where there is a fluctuating demand for steam has been developed by British Boiler Accessories Limited, of London, E.C.3. The method involves the use of a Lancashire boiler, which can be a steam accumulator or stand-by boiler, and which, by storing surplus steam produced during periods of small demand and releasing it during peak-load periods, enables the boilers to operate steadily at an even rate corresponding to the average steam consumption throughout the day. It is stated that the economy effected in fuel by avoiding banked boilers can be between 5% and 10%, the increase in efficiency also being reflected in reduced maintenance costs and the elimination of time lost in waiting for steam during peak periods.

In this new method, water is stored in a closed vessel which is partly filled, and is brought to boiling point by mixing it with live steam in a special external charging device. When this temperature is reached, a small amount of steam is formed, which, as it is unable to escape, increases the atmospheric pressure within the vessel. The temperature is then further increased by mixing the water with more steam and, when this reaches the boiling point corresponding to the increased pressure, another small amount of steam is produced, again increasing the pressure, and so on. When a valve at the top of the vessel is opened to release the steam for use, the pressure within the vessel is reduced and the water commences to boil, a certain amount being converted into steam, taking out a quantity of the latent heat from the remaining water, the temperature of which consequently drops until the balance between pressure and temperature is restored.

The external charging device, which operates in the same way as an injector, does not impair the capacity of the boiler to operate as a primary steam generator, when required. Live steam from the high-pressure main is injected through a nozzle, creating a strong suction effect which draws water from the stand-by boiler and injects it into a venturi tube, where the steam and water are thoroughly mixed, the steam being condensed. The

Tread and Trundle - Wear and Tear



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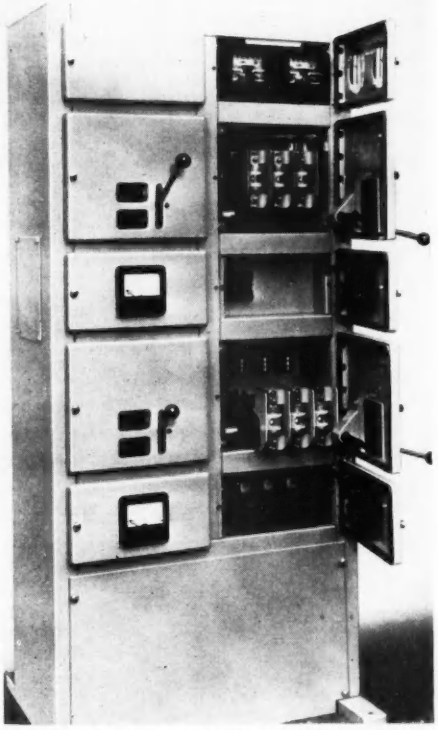
heated water rises to the upper part of the stand-by boiler and sets up a strong circulation of its water content, so that cool water is drawn from the lower part of the stand-by boiler, is heated in the charging device, and is returned to the upper part. The accumulator/stand-by boiler is thus charged by gradually raising the temperature and pressure of its contents. Discharge is controlled by a reducing valve, and charging can be controlled either manually or by a valve operated by the high-pressure main, in which case the accumulator functions automatically.

Heavy-Duty A.C. Fuse-Switchgear

Complying with B.S. 3185:1959 and built to exacting requirements for ensuring reliable service and easy maintenance, the new range of 550-V a.c. heavy-duty fuse-switchgear announced by George Ellison Limited, of Perry Barr, Birmingham, is available in sizes with current ratings from 100 to 600 A, and as three-pole or three-pole and neutral units. Any make of H.R.C. fuse can be fitted, provided that it complies with B.S.88:1952, Form B, and the exterior is of modern styling with clean, flush contours to eliminate dust traps. Interlocks are incorporated, ensuring safety in operation and maintenance.



Switches with current ratings up to 300 A are interchangeable, as also are those with ratings between 400 and 600 A. The mechanism is common throughout the range and provides a quick-make and quick-break action. A switch closes fully on fault, regardless of the speed at which the handle is operated, and cannot blow open under fault conditions. The contacts are of silver-plated copper, and the switches can therefore remain closed for long periods without detriment. The finger contact design is identical throughout the range, the only variant being the number of fingers per contact. The fuse-switches are mounted in a double-tier, two-way or four-way sheet-steel chamber. A cast-iron door, housing the telescopic operating handle and circuit-data plate, is fitted over each switch. Doors to carry instruments are also provided. The chambers can be supplied as components for bolting together on site.

The busbars are of electro-tinned copper, the standard continuous ratings available being 800-A phase with 500-A neutral, 1200-A phase with 800-A neutral, and 1400-A phase with 800-A neutral. The main connections are of electro-tinned copper, and the outgoing copperwork is reversible, permitting outgoing at the top or bottom of the chamber. The busbars and busbar connections comply with B.S. 159:1957. Cable fittings can be mounted on either the top or bottom of the chamber.

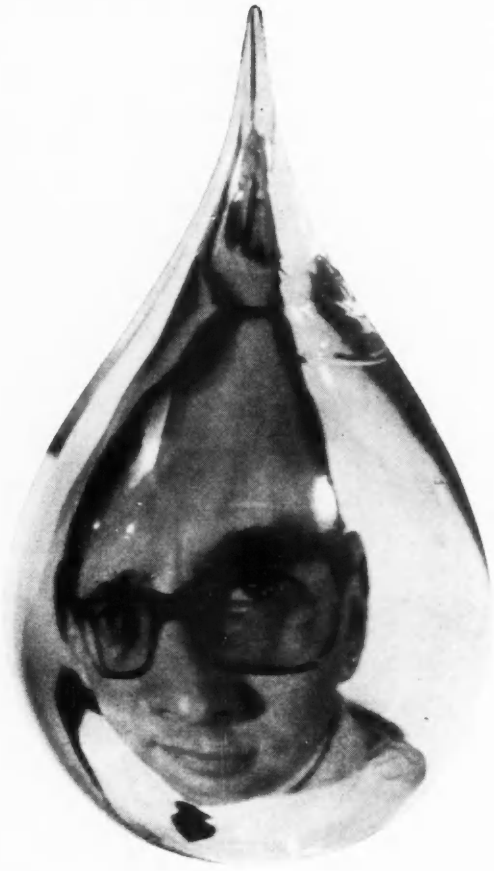
Machinable Steel-Bonded Carbides

Making it possible to produce in the shop with conventional tools carbide parts and tools which will withstand high temperatures and corrosive media, the latest addition to the range of steel-bonded carbides produced by the Sintercast Division of the Chromalloy Corporation, of Yonkers, N.Y., is " Ferro-Tic S ". This material is available in two grades, i.e., S-45 and S-55, both of which are produced by powder-metallurgy techniques, embedding tiny crystals of extremely hard titanium carbide in a relatively soft matrix of stainless steel. The resulting composite retains the properties of both of its constituents, combining the machinability and resistance to heat and corrosion of the stainless steel with the ultra-hardness of the titanium carbide.

The difference between the two grades lies in their relative machinability, one having a Rockwell C hardness of approximately 45 and the other 55. The softer of the two grades (Ferro-Tic S-45) can be machined readily with any single-point or multiple-point cutting tool, while Ferro-Tic S-55, the harder grade, is suitable only for the basic operations, i.e., sawing, turning, and drilling; milling or tapping is not recommended. Both grades can be ground and can be joined to other metals by welding or brazing. Blanks of both grades are normally available in rectangular form up to $1 \times 2 \times 7$ in., or as round bars up to 2-in. o.d. and 6 in. long, or 6-in. o.d. up to 2 in. long. However other sizes and shapes can be produced on special order.

At high temperatures and pressures, these stainless-bonded carbides are unusually stable. Thus, in tests on S-55 punches used to hot-coin nickel and cobalt alloy blanks at temperatures of 1600 to 1650°F and pressures of up to 50 tsi, it was found, after repeated pressings, that the punches developed no flaws or cracks, and that their dimensions did not change. Furthermore, no serious deterioration of the exposed surfaces due to oxidation was observed. Other advantages are that intricate parts can be machined from Ferro-Tic blanks quickly and easily, without resorting to the specially cast or formed shapes often necessary with cobalt alloys or conventional cemented carbides. Also, costly diamond grinding is avoided. After prototypes have been tested, and if quantity permits, shaped parts can be produced by powder-metallurgy methods, effecting still further savings in time and materials.

Typical applications for these carbides include valves or valve-seats for use in the chemical and food-processing industries, knives and choppers requiring the highest



LOOKING FOR FLUIDS—with exceptional thermal stability—fluids that are water-repellent and retain good dielectric characteristics over a wide range of temperatures — that resist oxidation—have low volatility and show little change in viscosity with temperature —are ideally suitable for use in damping mechanisms—as heat transfer media—and for use in hydraulic, springing and coupling devices—GET THEM FROM MIDLAND SILICONES.

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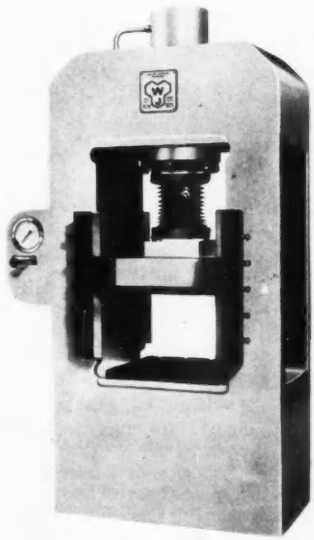
degree of cleanliness and corrosion resistance, seals for pumps, homogenizing valves, nozzles, gauges, high-temperature bearings, forming tools, and many other items where cast cobalt-base alloys or tungsten carbides might normally be employed.

The company also produces Ferro-Tic C, a machinable carbide using low-alloy tool steel as the matrix. This type is fully machinable, and can then be heat-treated to almost any desired degree of hardness. Owing to negligible warpage in heat-treating, the blanks can be machined to finished size, thus requiring no subsequent final grinding. Although this material is excellent for many tools and dies, it does not possess the heat and corrosion resistance of the two other carbide grades.

Frame Presses

A new range of frame presses in the "Prestige" series has been introduced by William Jones Ltd., of London, W.1, and includes 50-, 100-, 150-, 200-, and 250-ton units for bushing, bending, bonding, straightening, hot and cold forming of sheet and plate, and cold flow forging. These presses are powered by an electric motor directly coupled via a flexible coupling to a high-speed pump. Whenever possible, they are supplied as self-contained units with built-in pumping equipment, but this may be mounted separately, if specified. Oil is used as the hydraulic medium, providing simplicity of control, compactness, and minimum maintenance. All rams have power return. Control can be by fixed or pendant push-button, hand-lever, or foot-pedal. An easily adjustable calibrated pressure-control valve enables accurate pressures to be preset.



The main frame is of heavy welded-steel construction, designed to withstand maximum loads with a minimum of deflection. Four accurately machined slides engage with the moving platen to maintain true alignment. The platen and table of the press have machined surfaces, and tee slots are optional. The tables can also be arranged with a central hole for the ejection of punchings.

Surface-Grinding Machine with New Automatic Feed Control

As announced by Alfred Herbert Ltd., of Coventry, sole agents for the Lumsden range of surface- and tool-grinding machines, the latest addition to the range is their 90 ML surface-grinding machine (Fig. 1) which

Fig. 1

incorporates a new automatic feed control to the wheel-spindle ram. With this mechanism it is possible to preset accurately the amount of stock of be removed. Thus, for example, if 0·050 in. is to be removed and the estimated ratio of stock removal to wheel wear is 10:1, a trip dial is set to 55, i.e., 50 + 5, and a feed-rate adjuster is set to any one of ten feeds, depending on the surface area and material to be ground. The trip dial turns as the wheel descends, showing the amount the wheel still has to feed, and the feed stops when the trip dial registers zero. A second dial is provided for setting and adjusting the trip mechanism, this dial being graduated in very widely spaced 0·001-in. divisions. A close-up of the feed-control unit is shown in Fig. 2.

Another development on this machine is a new safety device which ensures that, should the current to the magnetic table fail, a relay starts the elevating motor of the wheel-spindle ram in the upward direction and all other motors stop. Thus, the wheel is clear of the work before the residual magnetism has decreased sufficiently

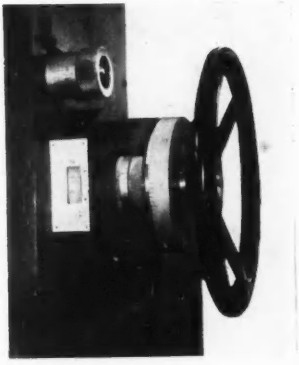


Fig. 2.

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to allow the work to be thrown off the table as it slows to a stop. Other electrical interlocks are provided to ensure safety of operation. For example, the feed handwheel must be pulled outwards before the feed motor can be started, ensuring that there is no danger of a blow from the spokes of the handwheel and that the "down" button is inoperative, should this be pressed instead of the "feed start". Another interlock ensures that the magnetic table must be energized before the spindle motor can be started.

Hand Embossing-Machine

Completely portable, but of precision construction, a new machine announced by the British Automatic Company, of London, E.C.2, is designed to emboss letters and numbers on a hard-wearing, corrosive- and chemical-resistant red vinyl plastic tape, which has a pressure-sensitive adhesive backing for instant and easy application to most smooth and clean surfaces. The plastic labels produced are embossed with permanently raised letters, $\frac{5}{32}$ in. in height, the tape being $\frac{1}{2}$ in. in width and supplied in rolls of 12 ft in length. The plastic labelling is self-feeding, all that is necessary being to dial the required letter or number and to squeeze the handle of the embossing machine. The cost is only a few pence per label, and the entire operation, including loading the tape, dialling the letter, squeezing the copy required, and cutting the finished label, takes less than one minute.

Because of its simplicity and portability (it is only $10\frac{1}{2}$ in. in length), the new machine, designated the "Midgie", is ideal for such jobs as labelling trees and shrubs; dials, controls, and gauges of all kinds; panel boards; containers for chemicals; and tools, instruments, vats, cables, etc. Also, as the plastic is waterproof, it can be used for labelling raw materials or parts stored in outdoor areas.

Small Precision Lapping Machine

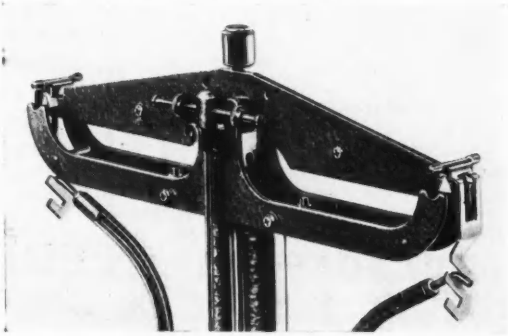
Expressly designed for the workshop or factory requiring a small low-cost precision machine for lapping the surfaces of components to high standards of flatness and surface finish, the new "Flexibox" Mark 15A lapping machine combines a large capacity with neat appearance and compactness, its maximum dimensions being only 32 × 22 × 20 in., enabling it to be bench-mounted and to minimize space requirements. In addition, anti-vibration pads eliminate the need for bolting down.

The new machine is a completely self-contained unit which can be used for the precision lapping of a wide variety of articles made from almost any constructional

material, including plastics, light alloys, ceramics, and ferrous metals. The lapping plate, 15 in. in diameter, is equipped with three wear-rings and provides a large capacity. Thus, for example, 66 components of 1 in. in diameter can be lapped simultaneously, while larger components, up to a maximum diameter of $5\frac{1}{2}$ in., can also be handled. An automatic flatness control device maintains the lapping plate truly flat at all times, so that the machine can be operated by unskilled personnel. The machine is also fitted with a timing device which can be preset for any desired interval (for normal use the range is 0 to 60 min), at the end of which the drive motor is automatically shut off. Coloured warning lights give a clear visual indication of whether the machine is in operation or not, so that constant supervision during running is unnecessary.

General-Purpose Laboratory Balance

Although essentially an inexpensive general-purpose instrument, the new Griffin "Minor" balance, produced by Griffin & George Ltd., of Alperton, Wembley, is rugged and accurate and incorporates a number of interesting analytical features, including a short beam for speedier weighing, single-limb bows carrying the moulded-plastic weighing pans, an inclined scale which rises with the pointer, a unique design of stirrups to protect the knife-edges, and a new design of pillar. An important feature is the improved assembly of the agate bearings, which are held in position by positioning screws, instead of being "drifted in" in accordance with usual practice. When the beam is arrested, all the agate bearings are relieved, as distinct from most conventional designs, in which only the central bearing is relieved.



The balance, which has a capacity of 250 grams and is sensitive to 2 milligrams, has a solid-type 8-in. brass beam, and the poising nuts are located near to the central

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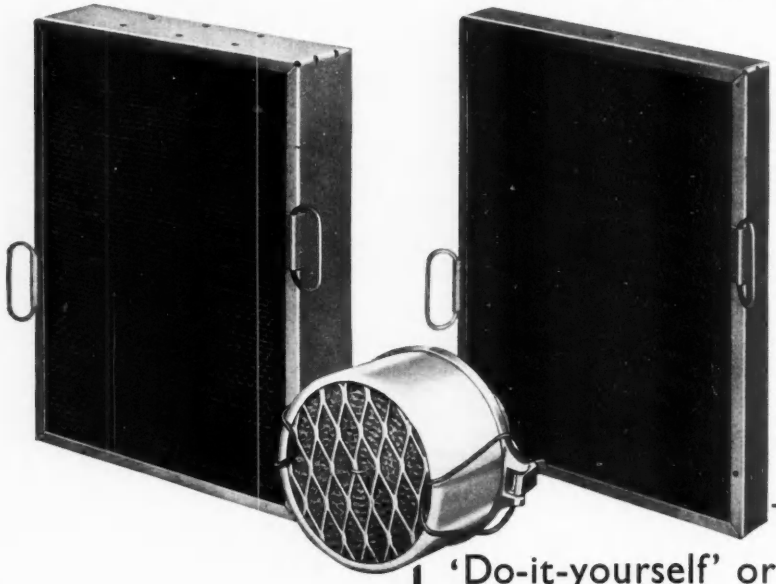

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4" thickness FAR-AIR viscous impingement filter panel

CENTRE
Circular FAR-AIR intake filter for reciprocating engines

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2" thickness FAR-AIR viscous impingement filter panel

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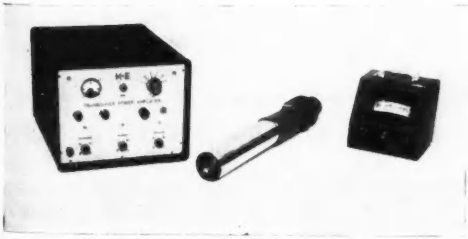
agate, where they cannot so readily contribute to accidental displacement of the beam and are not so easily damaged. This arrangement greatly reduces the overall length. When the balance is not in use, the beam is located by two central slots in the arrestment beam and kept horizontal by two locked screws. These slots are deep enough to prevent the beam from being accidentally dismounted and accurately guide it during assembly of the balance. The stirrups are of single-piece pressed-metal type with a double hook, and, when the beam is in the " rest " position, are lifted clear of the end knife-edges by the integral Y-arms of the arrestment beam.

The twin pillars supporting the arrestment beam are mounted on a rectangular plate, held in position by two nuts positively located beneath the base. Between the pillars passes a plated rod which carries the central bearing plane, the scale, and a rectangular, slotted cam-plate, fitting directly onto the crank-pin, eliminating the need for a connecting rod. The pointer, which carries an easily adjustable sensitivity weight, has an obliquely cut tip which moves over the curved, inclined scale, which rises with the beam, permitting comfortable reading without parallax. The novel form of bow adopted ensures that loading is completely unimpeded—a point of particular importance when the balance is used with a specific-gravity stool. An adjustable grub-screw in a lug on the base of each bow prevents the pan from swinging when the balance is arrested.

Electronic Auto-Collimeter for Direct Measurement of Angles

Capable of measuring the tilt of a reflective surface with respect to its axis with an extremely high degree of sensitivity and accuracy, the new electronic auto-collimeter announced by the Keuffel & Esser Co., of Hoboken, N.J., is stated to be ideal for such applications as checking the flatness of surface plates, monitoring the drift of gyroscopes, checking the straightness of machine-tool ways, and checking the run-out of precision bearings.

The instrument, which can read angles directly with a sensitivity approaching 0·02 sec, has three basic components, as shown in the illustration, these being (left to right) the power amplifier, the sensing unit, and the indicator. The output of the power amplifier is suitable for chart recording and, after suitable amplification, for a servo-system feed. The output voltage is ±15 V d.c. and is linear. The output impedance is approximately 600 ohms, 1 mA maximum.



The sensing unit, which transmits the signal (angular deviation) through the amplifier to the remote indicating unit, has an indicating range of ±25 sec, with a working distance of up to 30 ft between it and the reflecting surface. The sensing unit, which weighs about 9 lb and has an overall length of 17½ in., has a response of 0·02 sec, a built-in optical wedge for checking the calibration of the indicator, and a drift of less than 1% in 24 hr after initial warm-up. The sensing unit is connected to the power amplifier by 10 ft of cable.

The indicator has a three-position switch for selection of sensitivity, with ranges of ±1, 10, and 25 sec. The scale of the indicator is graduated to read directly in angular units, and electronic damping, with a 2-sec time constant, is provided. A chart recorder can be used in addition to the indicator, so as to provide a permanent record, or the signal can be fed into a servo-mechanism or computer. The power amplifier is connected to the indicator by 50 ft of cable, but this length can be increased to 2000 ft on special demand.

Damping Tapes for Vibration Control

(*Concluded from page 100*)

only now being initiated. However, much can be accomplished with multiple layers of established tapes or by devising individual special tapes. The problem in either case is to adjust the shear modulus G and thickness H_2 of the dissipative layer to achieve the best energy absorption consistent with easy handling and installation.

Most of the dissipative materials at present available can be obtained as mastic or as sheet material. In mastic form, they can be spread by hand or sprayed in place, with the metal foil laid over like wall-paper. For some materials, adhesives may be required to join the dissipative materials to the base metal and the constraining foil. Since the thickness of mastic is hard to control during application, designs based on mastic should call for a relatively thick dissipative layer. Normal variations during application will then be small compared with total mastic thickness, and variations in shear parameter g will be negligible.

Vibration damping is also useful for noise suppression. For this purpose light and effective designs employ a high-shear adhesive, applied to the foil as manufactured, or by spray at installation. Several aircraft manufacturers are applying this type of damping tape to aircraft fuselages as a noise-control measure and are also considering its use on airframes to control fatigue.

There is occasionally no dissipative material available to fit the necessary requirements for loss factor β, shear modulus G, and thickness H_2. If so, an " apparent " tape of the right proportions can be created by separating a thin tape (damping material plus constraining foil) from the plate with a shear-stiff spacer. For best results, the shear modulus/thickness ratio for the spacer material should be at least ten times that of the damping layer.

Thermal insulation can be combined with damping by replacing the spacer and/or metal foil by a thick layer of an insulating material such as foamed polyurethane or polystyrene. A possible loss in damping effectiveness by this method must be weighed against the gain in thermal insulation afforded.

At present, damping tapes (which sometimes look more like metal sheets) are applied to all, or nearly all, of the vibrating surface. Selective application—where and how much tape to apply for most damping per pound of added weight—is being investigated. Adding from 10 to 15% to the weight of the structure may be tolerable in most cases; however, localized application might cut this to perhaps 5%. Designing visco-elastic damping right into the structure, in sandwich form, is another very effective damping technique under scrutiny.

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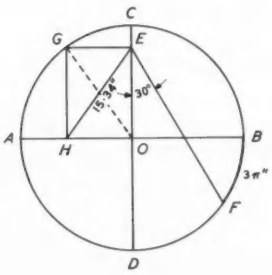
Results of Christmas Competitions

(1) THE PROBLEM OF THE RED HERRINGS



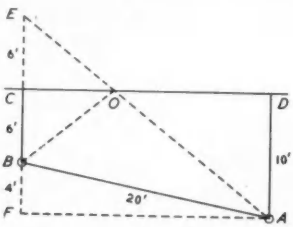
A fishmonger has a circular slab, of which AB and CD are diameters at right angles to one another. On the slab is displayed a red herring EF, lying at an angle of 30 deg. to the diameter CD, the length of the arc BF being 3π in. EG is another herring, which lies parallel to AB, while herring GH lies parallel to diameter CD. The herring HE measures 15·34 in. in length.

From this admittedly unusual way of displaying fish, can you deduce (to two decimal places) the diameter of the fishmonger's slab? (The value of π should be taken as 3·142.)

As anticipated, all competitors spotted that the title of this problem was aptly named and that EF and the arc BF were indeed " red herrings ". Consequently, all solutions to this problem were correct and were based (with the exception of two entries) on the following:—

As, by construction, $EGHO$ is obviously a rectangle, its diagonals must be equal in length. Hence, $OG = HE = 15{\cdot}34$ in. As OG is the radius of the circular slab, its diameter must therefore be $2 \times 15{\cdot}34 = 30{\cdot}68$ in.

(2) THE PROBLEM OF THE LAZY CARETAKER



In our office-block, the caretaker who looks after the heating system usually sits at his desk A, which is 10 ft from the edge of a coal-bunker CD. At regular intervals, he picks up his shovel, which he keeps within reach of his desk, takes a shovelful of coal from the bunker, and replenishes the furnace B, which is 6 ft from the edge of the bunker and 20 ft from his desk.

Now, our caretaker, who is rather lazy, on one occasion decided that, the next time he had to throw a shovelful of coal on the fire, he would walk the shortest possible total distance from his desk to the bunker and back from the bunker to the furnace. Can you indicate his shortest possible route and say how long it is (to one decimal place)?

Strangely enough, this problem seemed to cause the most difficulties, more than 20% of the solutions received being incorrect. Most entries were based on the simple " mirror " solution given below, though some utilized rather lengthy and complicated methods based on differential calculus (occasionally with disastrous results). Also, some competitors made use of false assumptions, e.g., that angle BOA must be a right-angle, while others merely slipped up in their arithmetic.

The simplest solution is as follows:—

Produce BC to E, so that $BC = CE$.

Join AE to intersect CD at O. Join OB.

As triangles OCB and OCE are, by construction, equal in all respects, $OB = OE$.

Now, the shortest distance between A and E is the straight line AOE and, as $OB = OE$ and $BC = CE$, the required shortest route $AO + OB = AE$.

If AF is drawn parallel to CD to meet CB produced at F, AFE is a right-angled triangle, so that

$$AE^2 = EF^2 + AF^2$$
$$= (6 + 6 + 4)^2 + (20^2 - 4^2)$$
$$= 256 + 384 = 640.$$

and $AE = 25{\cdot}3$.

Therefore, the shortest route $AO + OB = 25{\cdot}3$ ft.

(3) THE PROBLEM OF THE GENERATOR AND ITS TURBINE

After being in service for some time in a power station, a steam turbine had to be provided with a new generator. The turbine is now $2\frac{1}{2}$ times as old as the new generator was when the turbine was as old as the generator is. When the generator is as old as the turbine is now, the combined ages of the generator and turbine will then be 24 years plus the present age of the generator. What are their respective ages now?

Competitors apparently found this problem far less troublesome than the previous one, only 5% of the solutions received being incorrect. Most entries were based on the simple algebraic solution given below, though a few utilized graphical methods (not always correctly).

One algebraic method of solution is as follows:—

If x and y are the respective present ages of the turbine and the generator, then $(x - y)$ is the difference in their ages, since the turbine is older than the generator.

When the turbine was as old as the generator, i.e., y years old, the generator was $y - (x - y) = 2y - x$ years old.

Hence, $2\frac{1}{2}(2y - x) = x$

or $5y - 2\frac{1}{2}x = x$

or $10y - 5x = 2x$

so that $10y = 7x$ .. .. (1)

When the generator is as old as the turbine is now, it will be x years old, and the age of the turbine will then be

$x + (x - y) = 2x - y$ years.

Hence, $x + (2x - y) = 24 + y$

or $3x - 2y = 24$

or $15x - 10y = 120$ .. .. .. (2)

Substituting the value of $10y$ from eq. (1),

$15x - 7x = 120$

or $x = 15$ years.

Therefore, from eq. (1),

$10y = 7 \times 15 = 105$

or $y = 10\frac{1}{2}$ years.

Therefore, the present age of the turbine is 15 years and the generator $10\frac{1}{2}$ years.

In general, the response to these mathematical problems was quite satisfactory, and entries were also received from various countries abroad, including the U.S.A., Canada, India, Iran, Italy, France, Holland, Germany, Sweden, Denmark, Norway, and Finland.

The first three correct solutions opened on March 1 were received from the following competitors, to each of whom 5-guinea awards have been sent:—

Mr. H. S. GATES, Westinghouse Electric Corporation, 469 Sharpesville Avenue, Sharon, Pa., U.S.A.

Mr. P. W. LANSDOWN, Large Machines Division, The General Electric Co. Ltd., Witton, Birmingham 6.

Mr. GUNNAR OXAAL, Teknisk Ukeblad, Kronprinsens Gt. 17 (VII), Oslo 9, Norway.

(Solution to crossword puzzle on page 143)

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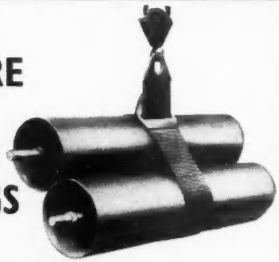

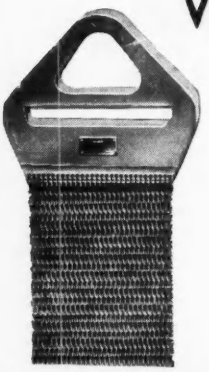

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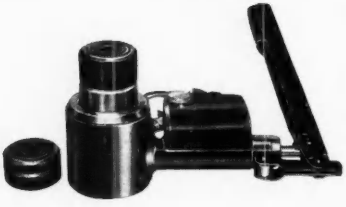

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Solution to Cryptic Crossword Puzzle

With the exception of two or three (unfortunately incorrect) solutions from Canada and the U.S.A., all entries for the crossword puzzle were from the U.K. This, of course, was only to be expected because, although crosswords themselves are of American origin, cryptic puzzles of this type are more or less a British innovation and have, indeed, been commonplace in Great Britain for many years, whereas they are hardly known at all in the U.S.A. It is probably for this reason that one American entry was chiefly remarkable for the fact that about half the clues were solved incorrectly.

Of the total number of solutions received, about 70% were entirely correct. Curiously enough, of the 30% incorrect solutions, practically all were confined to errors in the answers to the clues for 3 *dn.* and 15 *ac.*, which were given as *reservations* and *log table* respectively. While it is true that *log table*, in place of *log scale*, might be acceptable as a suitable answer to 15 *ac.*, it is impossible to see how *reservations* fits in with the context of 3 *dn.*, i.e., " Confine charged particles " = *restrict-ions.*

The first three correct solutions opened after March 1 were received from the following competitors, to each of whom 5-guinea awards have been sent:—

1C	O	2M	P	3R	E	4S	S	5O	R	■	6U	7S	E	8S
U	■	I	■	E	■	P	■	R	■	■	■	O	■	T
9T	E	L	E	S	C	O	P	I	C	■	10F	L	U	E
S	■	L	■	T	■	T	■	G	■	11T	■	V	■	A
■	12P	I	E	R	■	13W	E	I	G	H	B	E	A	M
14F	■	N	■	I	■	E	■	N	■	E	■	N	■	I
15L	O	G	S	C	A	L	E	■	16P	R	O	T	O	N
A	■	■	■	T	■	D	■	17C	■	M	■	■	■	L
18M	A	19T	R	I	X	■	20M	O	N	O	X	21I	D	E
E	■	I	■	O	■	22S	■	A	■	S	■	N	■	T
23P	O	T	E	N	T	I	A	L	■	24T	A	C	K	■
R	■	R	■	S	■	L	■	D	■	A	■	O	■	25L
26O	V	A	L	■	27R	E	L	U	C	T	A	N	C	E
O	■	T	■	■	■	N	■	S	■	I	■	E	■	V
28F	U	E	L	■	29S	T	A	T	I	C	A	L	L	Y

Mr. A. R. ALDREN, Imperial Chemical Industries Ltd., Billingham Division, Billingham, Co. Durham.
Mr. J. M. BOYD The Electric Construction Co. Ltd., Bushbury Engineering Works, Wolverhampton.
Mr. J. A. NICHOLSON, D. & R. Dept., Crompton Parkinson Ltd., Chelmsford, Essex.

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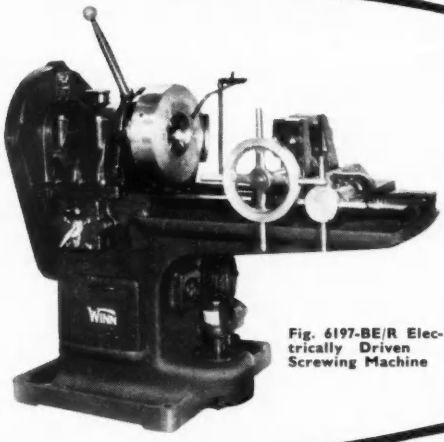
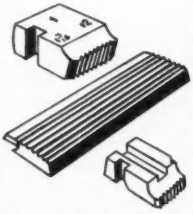


Fig. 6197-BE/R Electrically Driven Screwing Machine



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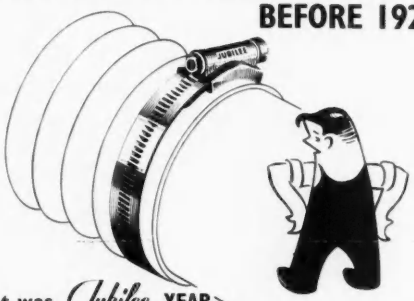

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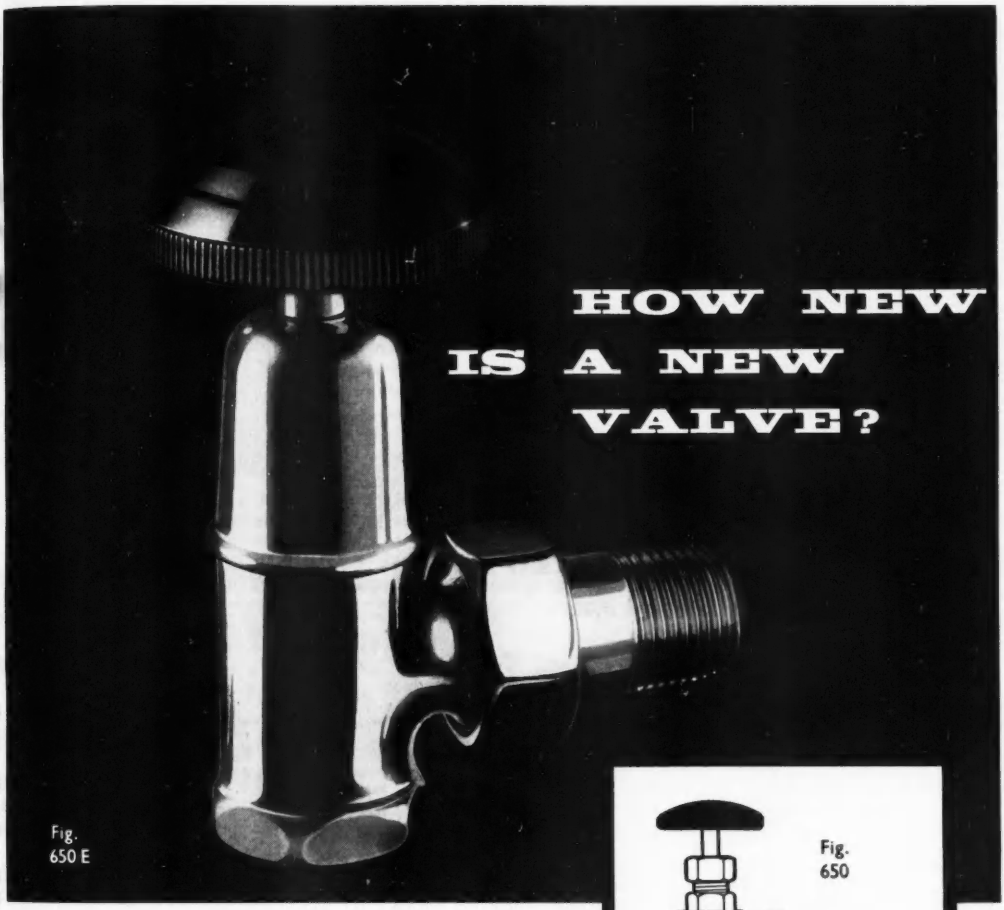


Fig. 650 E

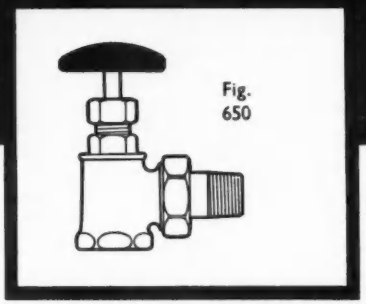
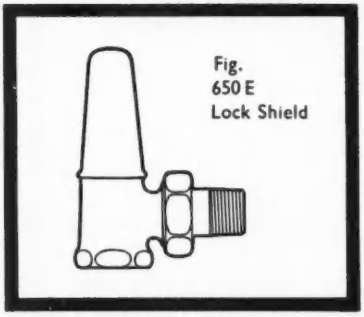


Fig. 650



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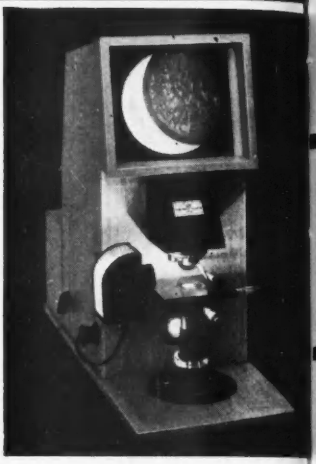

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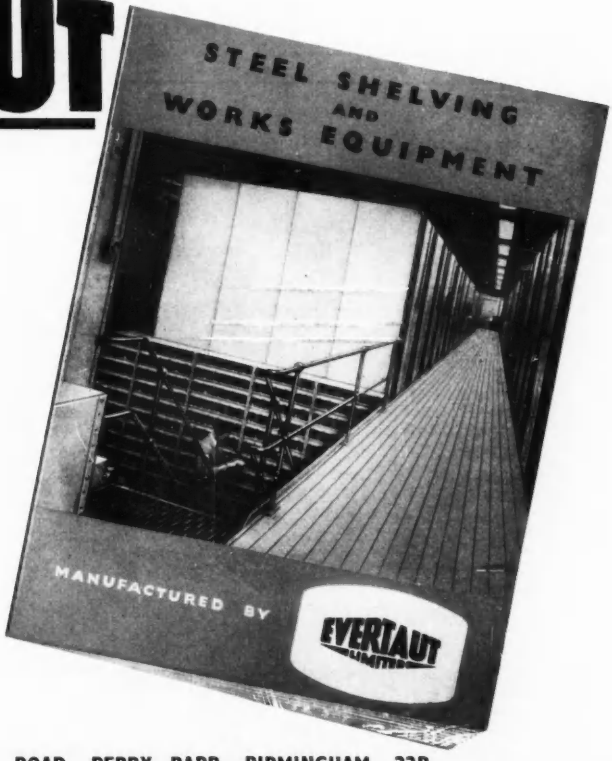

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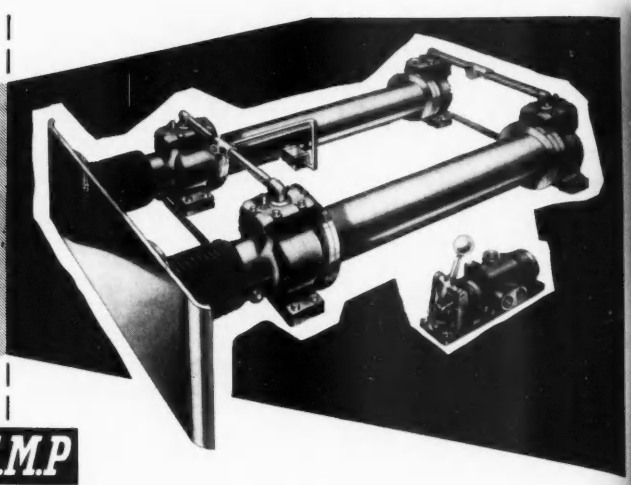

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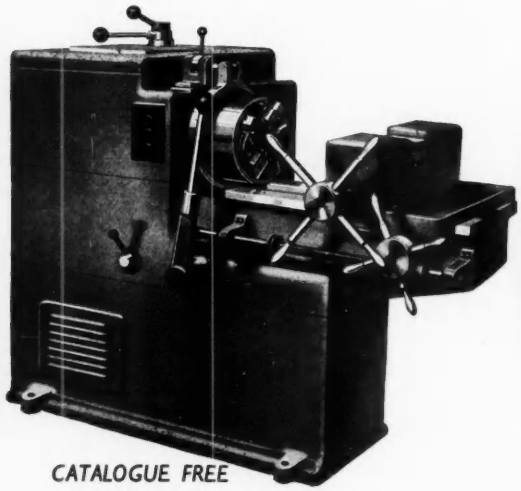

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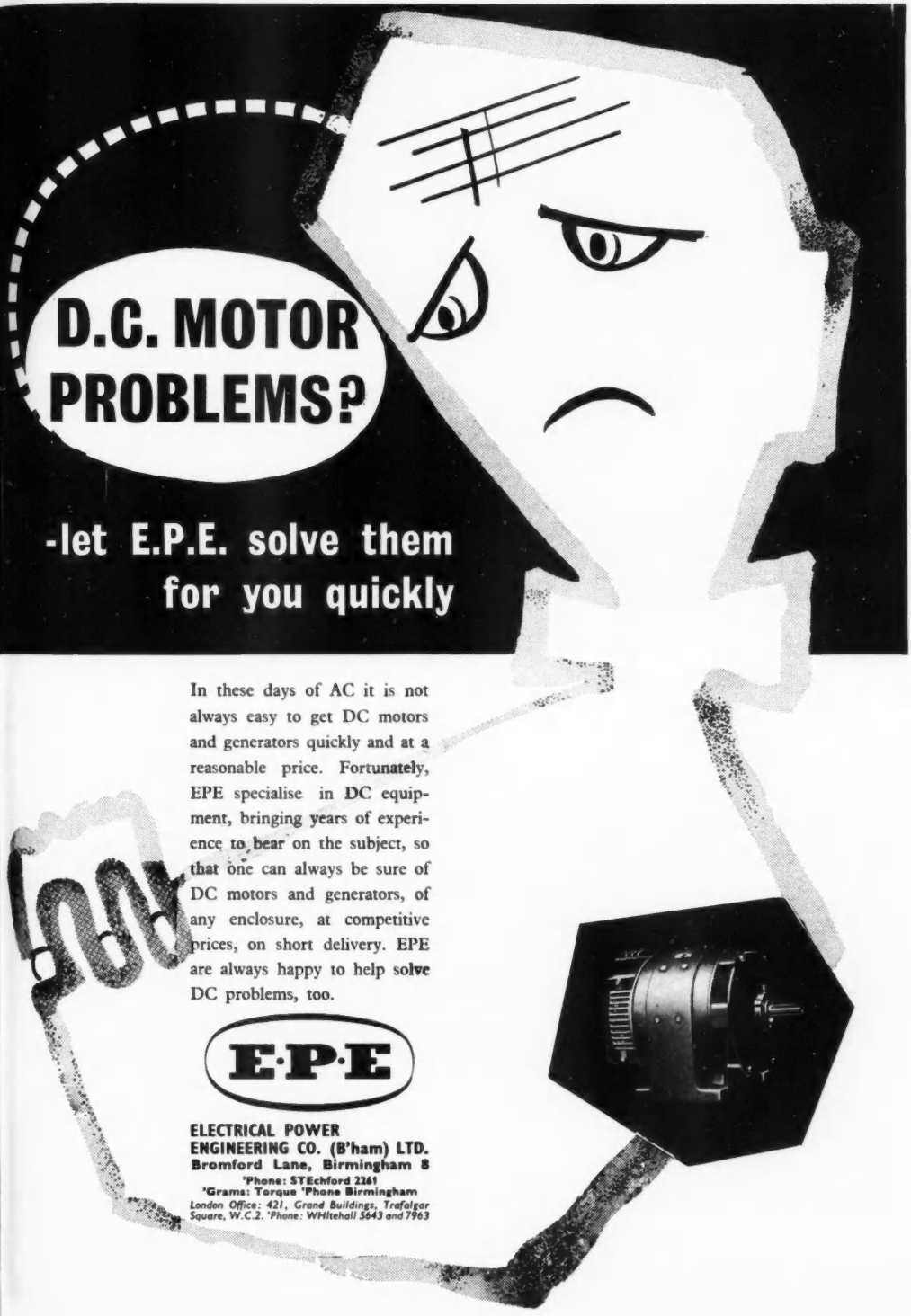

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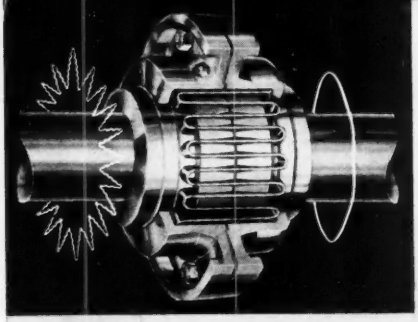

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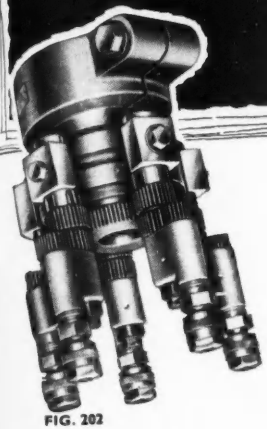

FIG. 202

multi-spindle tapping attachments

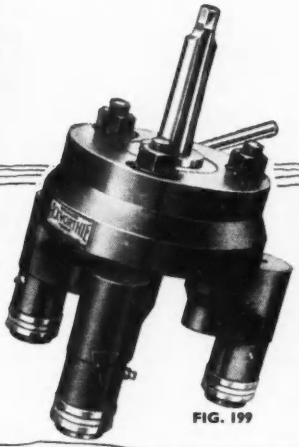

FIG. 199

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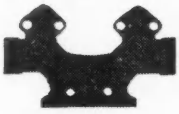

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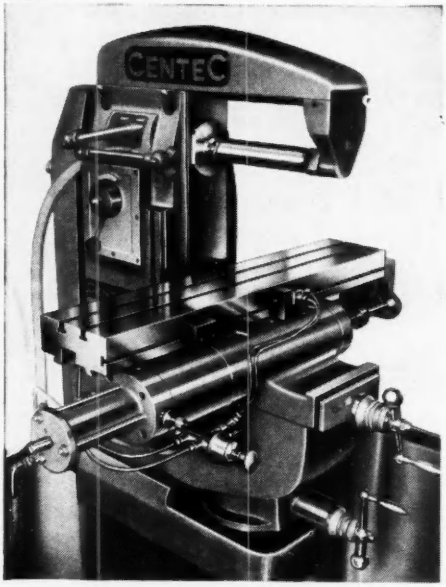

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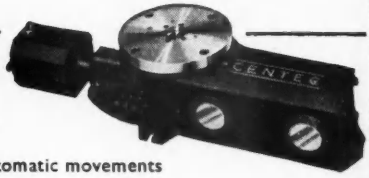

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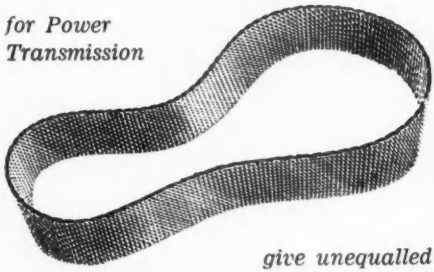

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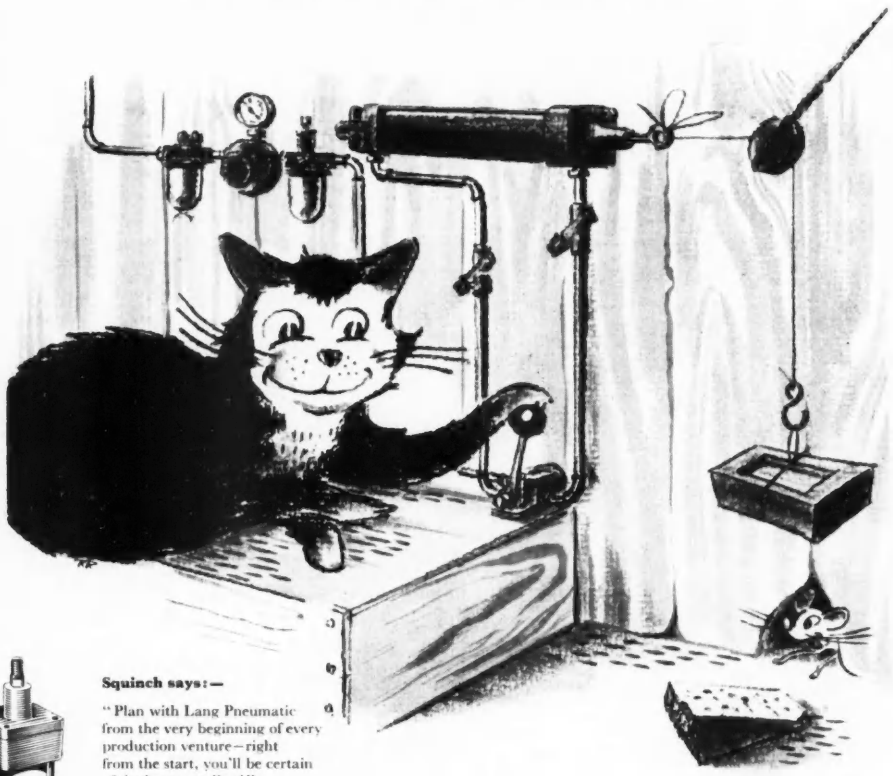

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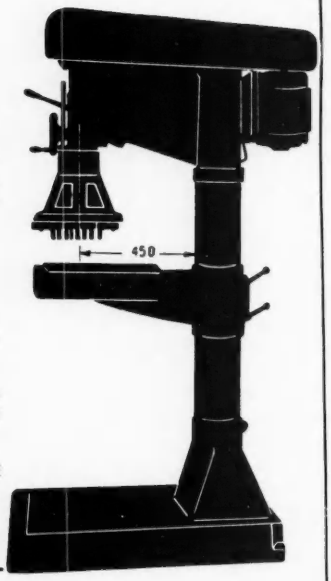

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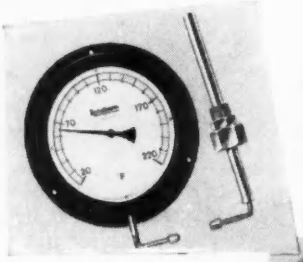

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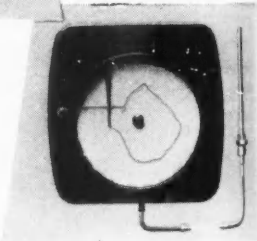

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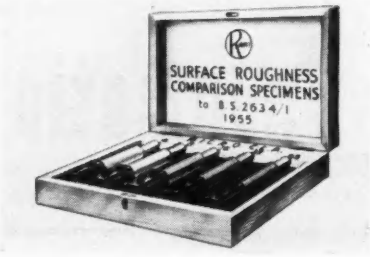

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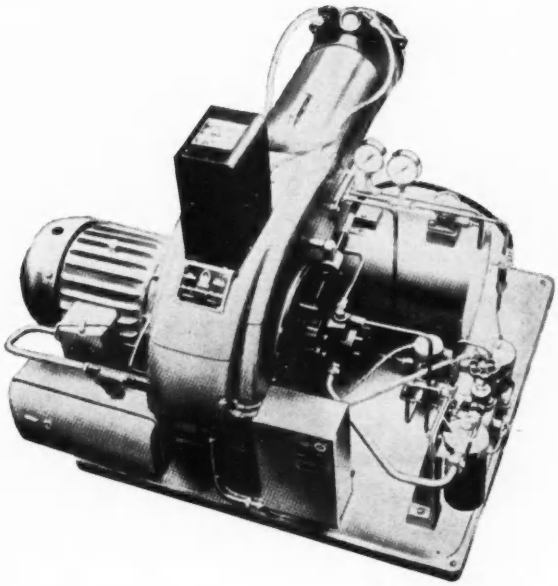

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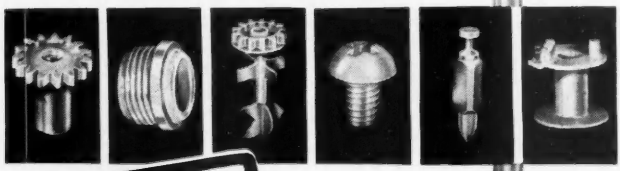

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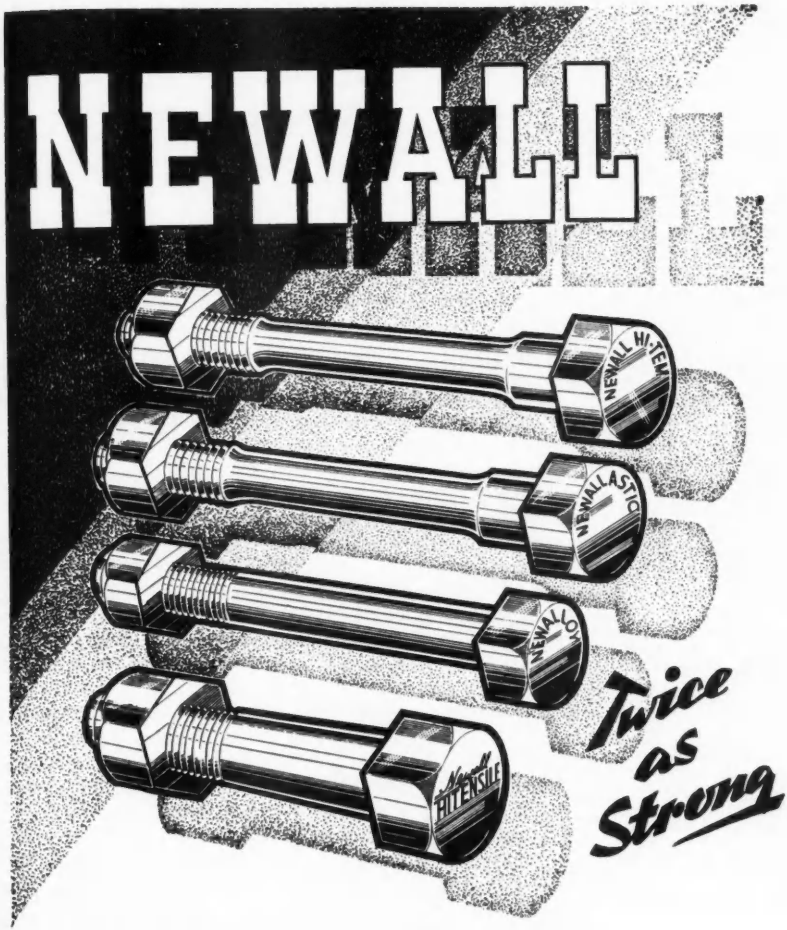

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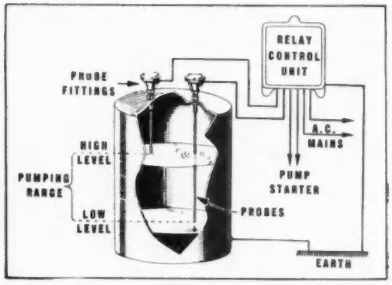

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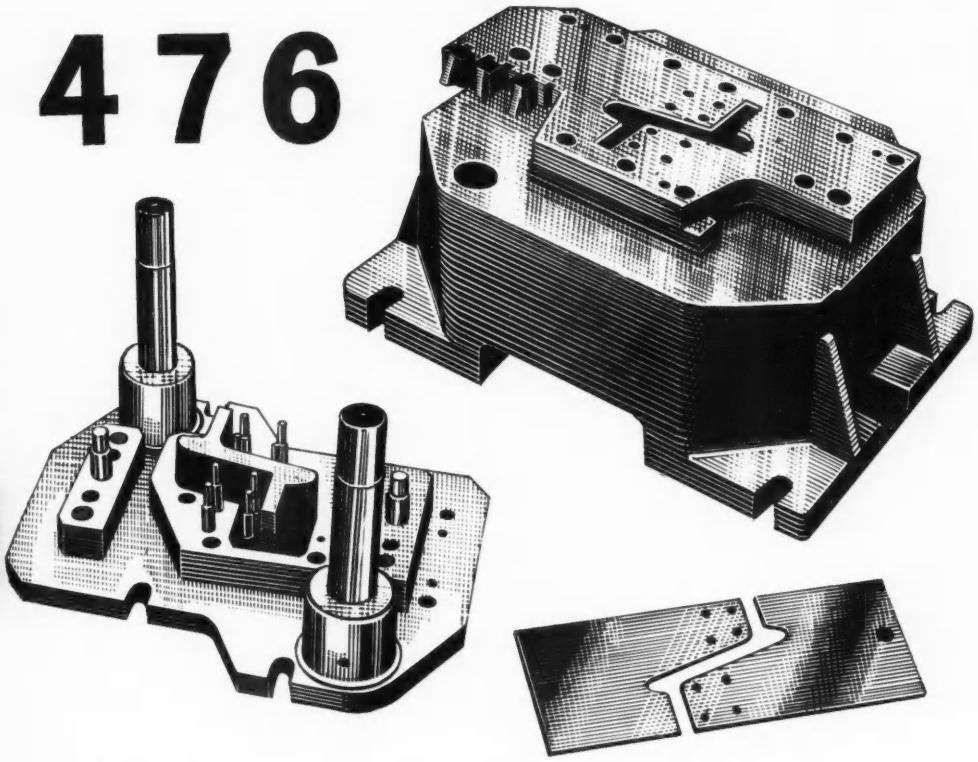

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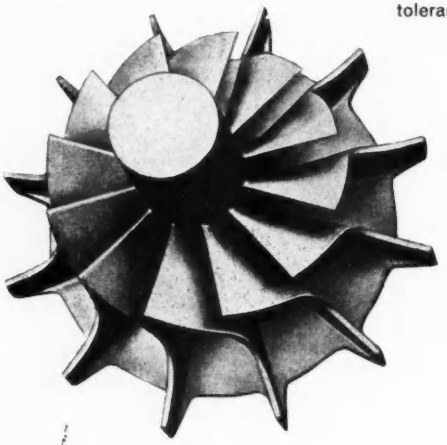

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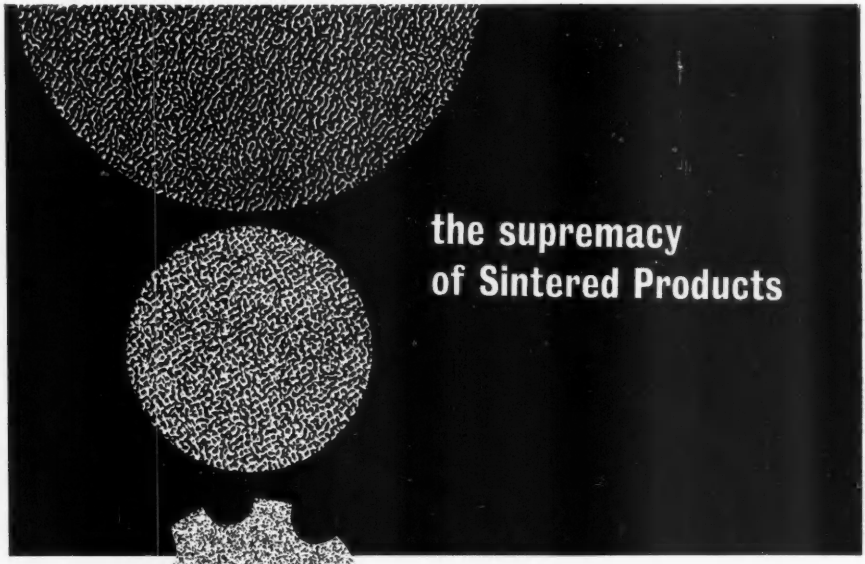

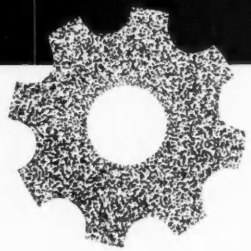

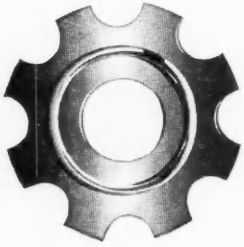

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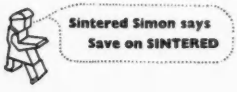

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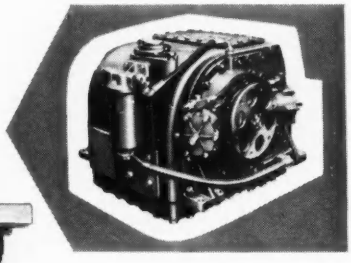

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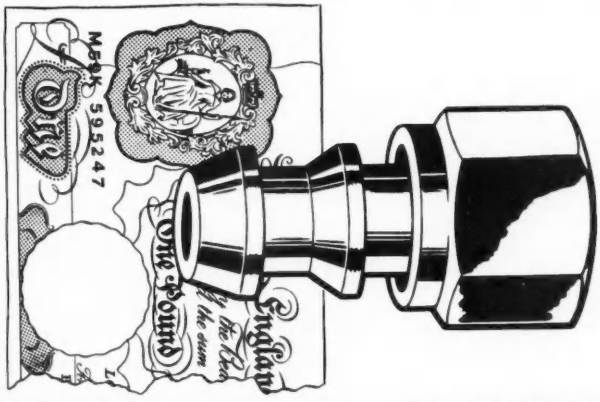

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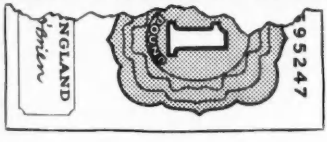

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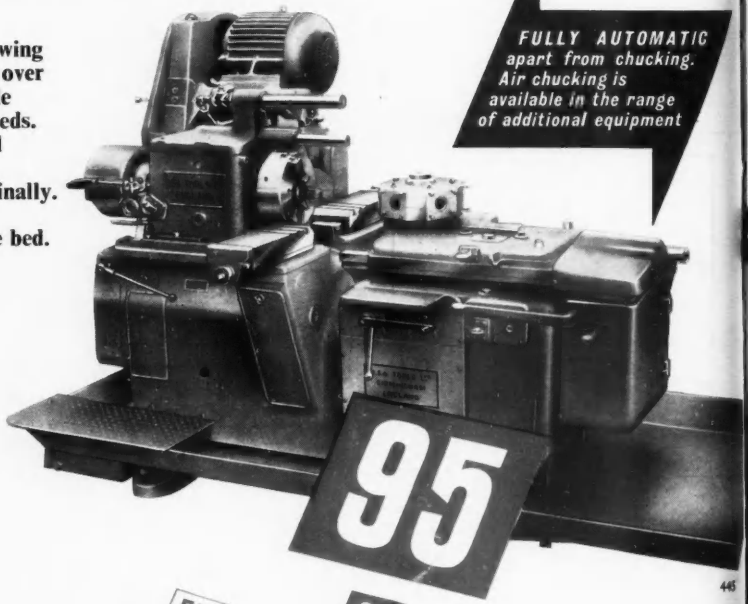

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